A SYMPOSIUM ON THE VALUE OF COMMERCIAL FISHERIES TO ALASKA

**Presented at the 15th Annual Meeting of the American Fisheries Society
Juneau, Alaska
November 14-17, 1988**

SPECIAL PUBLICATION NO. 1

Alaska Department of Fish and Game
Division of Commercial Fisheries
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February 1989

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TABLE OF CONTENTS

FOREWORD

In November 1988 the Alaska Chapter of the American Fisheries Society held its annual meeting in Juneau. The theme of the meeting focused on the value of fisheries to Alaska and included a session entitled, *The Value of Commercial Fisheries to Alaska.* Chaired by Ken Parker, director of the Division of Commercial Fisheries, Alaska Department of Fish and Game, the session provided an overview of a wide range of information and issues related to commercial fisheries economics, information on the economic benefits of fisheries throughout the state, and comparisons of Alaska's commercial fishery values with other states and the nation. The presentations have been assembled in these proceedings primarily for the use of individuals, agencies, and governmental bodies that set policies, laws, and directions for commercial fisheries in Alaska and for those who may otherwise be able to apply this information to some useful purpose.

Prior to the 1980's little was known about the economic importance of Alaska's commercial fisheries. George Rogers and Donna Mayer, in an evaluation of 1979 data, were the first to document the economic importance of commercial fishing in Southeast Alaska. Comprehensive statewide assessment of the economic importance of commercial fishing in Alaska was first conducted by Matthew Berman and Teresa Hull for the 1984 fisheries and more recently by Hans Radtke and William Jensen (Resource Valuations, Inc.) in a study of the 1986 west coast seafood industry. Interest in our commercial fisheries has been increasingly heightened by major changes in Alaska's seafood industry, including Americanization of offshore groundfish fisheries, increased capital investments in shore-based processing capacity, and dramatic increases in total exvessel catch values (doubled over 1984-1987).

Management has begun to feel the impact of this heightened interest in fishery values, impacts intensified, in part, by the Magnuson Act. This 1976 federal law replaced the *biological yield* objective for federal fisheries management with a yield concept based on economic, social, and ecological factors: *optimum yield*. This same management concept exits in the Alaska Constitution, Article XIII, which requires renewable resource management provide a sustained yield for the *maximum benefit* of all Alaskans. Maximizing economic values and allocating economic benefits will continue to complicate fishery management into the foreseeable future, but the potential for increasing fishery values seems to warrant support of additional management and research efforts.

We thank the American Fisheries Society and the organizers of the Chapter Meeting for having the foresight to bring attention to the importance of fishery economic values. Their efforts combined with those of the speakers has shown that all Alaska's fisheries, not just it's commercial fisheries, play a major role in shaping the Alaskan economy through the creation of both jobs and income.

Excluding the value of other Alaskan fisheries, its commercial fishing industry alone has displaced oil and gas as the state's most valuable private industry. In contrast to oil and gas, which are finite and therefore inevitably destined to diminish in importance, our fishery resources are renewable and can only grow in importance, if properly managed. Clearly, our fishery resources are a natural endowment, our original 'Alaska Permanent Fund.'

BRISTOL BAY MANAGEMENT COSTS AND FISHERIES VALUE

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INTRODUCTION

The Bristol Bay sockeye salmon fishery is one of the most intensively managed fisheries in the world. Fishing is restricted to terminal harvest areas (Figure 1) so that escapements can be achieved for individual river systems. There are a variety of data collection projects, many of which provide in-season or real time information on run strength. These include tower projects where escapement are enumerated on all major river systems, river test fisheries on three river systems to provide more timely escapement data, smolt enumeration projects on six river systems to provide more accurate pre-season forecasts and escapement goal evaluation, catch and escapement sampling for age composition on all districts and river systems and stock separation in the eastside fishing districts to improve estimates of production.

The objectives of the ADF&G program are straightforward: to provide the information to define optimal escapement goals and the information required to regulate the fishery to achieve these goals under extremely variable and unpredictable run strengths.

This management system is expensive, the State's General Fund investment in this program in 1987 was approximately 1.9 million dollars per year. Is this intensive fisheries management practice worth the cost of implementing it?

HARVEST MANAGEMENT

Figure 2 shows the historical Bristol Bay catch levels since 1900. In the early 1970's the Bristol Bay fishery was almost non-existent. Since 1978, catch magnitudes have exceeded historical maximum levels. The ex-vessel value of the Bristol Bay catch has consistently exceeded 100 million dollars since 1979, and the management costs almost insignificant compared to the value of the Bristol Bay catch to the fishermen. Simplistically, it may seem that the ADF&G program is worth the cost, because current catch levels are high and appear to be sustainable. This argument is flawed because other factors such as favorable climatic regimes and reductions of high seas interceptions, which are independent of ADF&G management regime could be responsible for the resurrection of the Bristol Bay fishery. Perhaps these catches can be sustained under a less expensive management regime.

Prior to 1924 Bristol Bay fisheries regulations consisted of keeping the fleet below the intertidal zone and reducing its efficiency. Powerboats were banned in 1923, and gill net mesh size was restricted. The White Act of 1924 sought to evenly divide each river's catch and escapement, but this was never achieved. Fish counting weirs were erected on some rivers as a means of assessment but they proved costly and inefficient. Consequently, escapement magnitudes were poorly accounted for and management was often ineffective because of remote (Washington, D.C.), regulatory control. The early Bristol Bay fishery was essentially a quota fishery being limited by canning capacity.

During the 1940's and 1950's more cost effective monitoring techniques were developed, including counting towers and more efficient methods for aging scale samples. These factors and the establishment of local regulatory control culminated in the implementation by the state of Alaska of real time fishery management system to achieve escapement goals by river system. The ADF&G Bristol Bay management system evolved steadily since statehood (Table 1). The evolution has been in two dimensions, the first being altering management policies by periodically modifying escapement goals to achieve maximum sustained yield, and the second is adding program elements. These additional programs have provided better and more timely information to make management decisions. In order to achieve escapement goals, fishing must be curtailed during years of poor runs and expanded in years of strong runs. Thus, precise managment requires prior knowledge of run strength. Management precision has increased with added program elements (Table 1).

COST EFFECTIVENESS OF MANAGEMENT

The Bristol Bay management system has become more expensive to implement with time. It should be clear that if the value of sustained catch levels expected under the present management regime are high relative to the costs of the program, then the Bristol Bay management system is cost effective.

To evaluate the cost effectiveness of the Bristol Bay management system, I used a stochastic computer simulation model (Figure 3) to calculate expected sustainable harvest under the various historical management regimes used in Bristol Bay. The model considers five stocks: Ugashik, Egegik, Naknek, Kvichak, and the combined river systems of the Nushagak District.

The model recursively constructs the current run from production of previous brood years, allocates the run to catch and escapement, then projects future year returns from that escapement. The total returns from a given escapement are calculated using the Ricker spawner/recruit model fitted to historical data. These returns are allocated to future run years based on an age-at-return relationships. The details of the model are given in Eggers and Rogers (1987).

Average catches were simulated for various historical management regimes. Each management regime is characterized by a harvest policy and level of management precision. For each simulation, the current year run is allocated to catch and escapement based on an algorithm with the harvest policy and level of management precision expected for the management regime being evaluated.

A key element of the model is the Ricker-type compensatory relationship between escapement and return (Figure 4). The conclusions of this analysis rest on this assumption. Under the Ricker model, maximum yield occurs at intermediate levels of escapement, and the greatest sustained catch occurs when individual stocks are managed for fixed optimal escapement goals. This policy may or not be cost effective, depending on the management costs in implementing this policy.

Figure 5 shows the escapement return data for the Ugaghik, Egegik, Naknek and combined Nushagak District river systems. There is strong evidence for compensation in this data. The production is much greater in the recent period, since 1974 brood year. This may be due to more favorable environment or the fact that production was underestimated in the early years because of high seas interceptions. The Ricker curves were estimated from the recent data, which more accurately reflect the production expected from a given level of escapement.

Figure 6 shows the relationship between smolts produced and parent escapement for the Kvichak River system. There is clear evidence for compensatory production. Note also that production was less for the 69 - 72 brood years, a period of extremely cold environmental conditions.

Random fluctuations in production that corresponded to historical deviations from average production were used in the model to simulate these environmental effects.

Figure 7 shows the historical trends in average management error observed for Bristol Bay. Management error is expressed as the deviation in rate of exploitation achieved and that necessary to meet the desired escapement goal. Positive deviations reflect escapements less than desired and negative deviations reflect escapements greater than desired. Note the decreasing trend in absolute value of management error.

Figure 8 shows the frequency distribution for managment error, pooled for various years and fishing districts. Management error is a stochastic phenomenon; errors are normally distributed when runs are greater than the escapement goal, and uniformly distributed when runs are less than the goal. This model was used to simulate year to year variability in management precision. In simulations, various levels of management error historically realized by the Bristol Bay management system can be manifested in the standard deviation of the normal pdf, and the range of the uniform pdf.

Figure 9 shows the results of simulation of average catch (i.e., sustainable harvest level) expected for a variety of management errors. These curves are provided for four harvest policies: 1) the pre-1960 50% rate of exploitation harvest policy under the White Act, 2) fixed escapement goals with the 1965 goals, 3) fixed escapement goals with the 1984 goals, and 4) a theoretical maximum based on a preliminary analysis altering the Kvichak escapement goal policy. Note that sustainable harvest level increases both with a decrease in management error and with evolving management policies. There is a substantial increase in sustained harvest level with fixed escapement goal harvest policy.

I have calculated a cost benefit ratio for continued investment in the Bristol Bay management system. These calculations assume that:

1. The harvest policy and level of management precision at the time to the investment were those achieved for the 1984 program.

2. Additional harvesting and processing costs at the increased catch levels are negligible.

3. Capitol investments for current processing and harvesting capacity were not considered.

4. Capitol investments to develop the ADF&G management system to the 1984 level were not considered.

Expenditures for the Bristol Bay management program during the period 1967 - 85, have increased at $78.3 thousand dollars per year (Figure 10). This has resulted in an 0.8% per year reduction in absolute management error (Figure 11). Based on the results of the simulation study, a 0.8% reduction in management error under the 1984 policy would result in an increase in sustainable catch of 300 thousand fish. That harvest is worth 1.8 million if the average weight were 6 lb and the ex-vessel price was $1 per lb. Since sockeye have an average age at return of 5 years, the benefits from the investment in the ADF&G program would not accrue until 5 years in the future. Those benefits must be expressed in present value in order to be compared correctly to the costs in a costs benefit ratio. The discount factor is 0.77 and was calculated assuming annual discount rate of .05%.

The estimated ratio of benefits (B) to costs (C) is calculated as follows:

$$\frac{B}{C} = \frac{\text{Discounted ex-vessel value of increased catch}}{\text{Additional investment in ADF\&G program}}$$

$$= \frac{\$1.8 \text{ million} \times 0.77}{\$78.3 \text{ thousand}}$$

$$= 18$$

This calculation was not a true benefits/costs calculation because all costs and benefits expressed at present value were not considered. This is reflected in the list of assumptions. However, this value does demonstrate that further investment in the ADF&G management program is cost-effective.

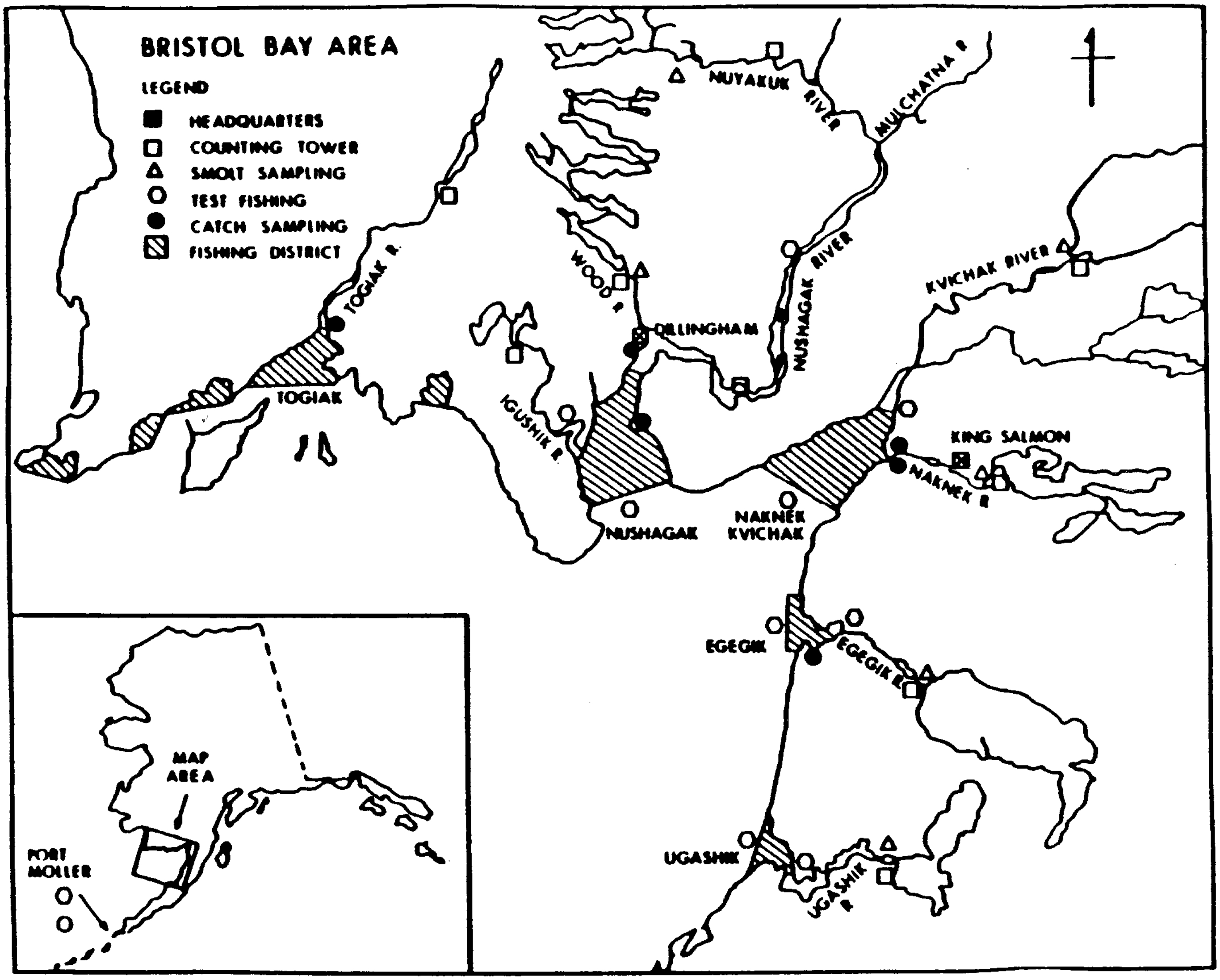

Figure 1. Bristol Bay sockeye salmon river systems, fishing districts, and sampling programs of the Bristol Bay management system.

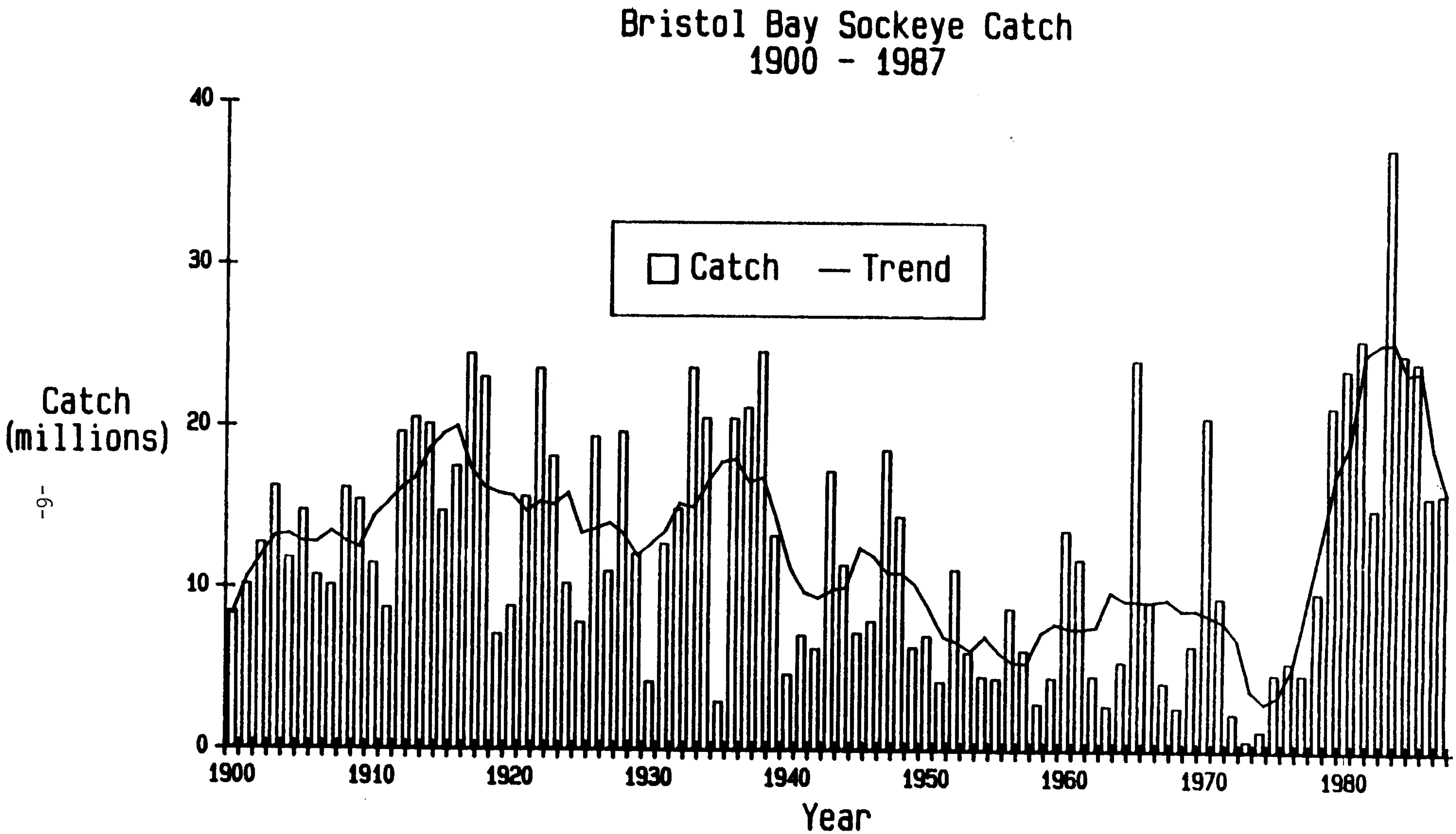

Figure 2. Bristol Bay sockeye salmon catch, 19-0-1987 and trend in catches, estimated by 3-year moving average.

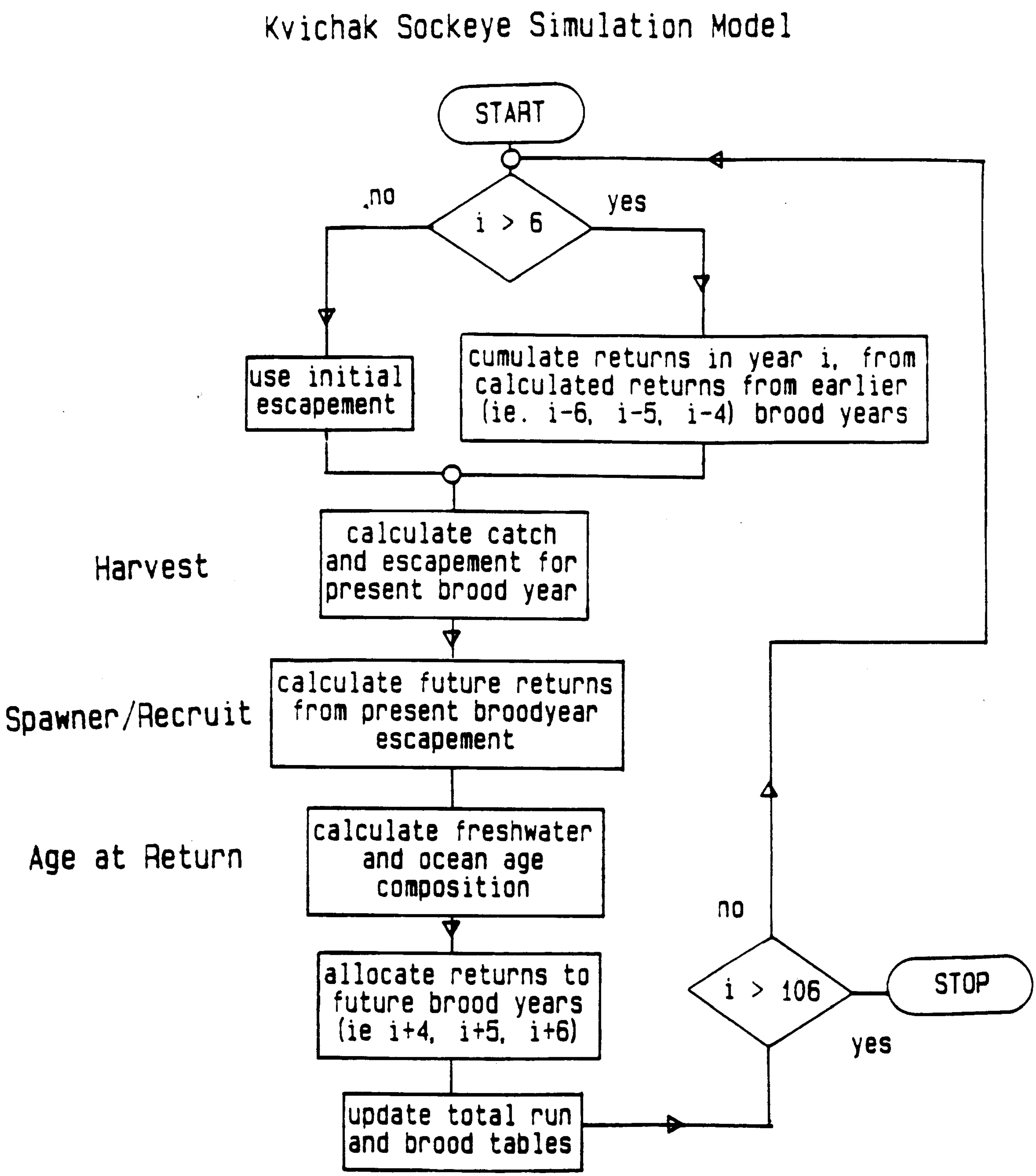

Figure 3. Elements of the model used to simulate the effect of management regime on average catch of Bristol Bay sockeye salmon.

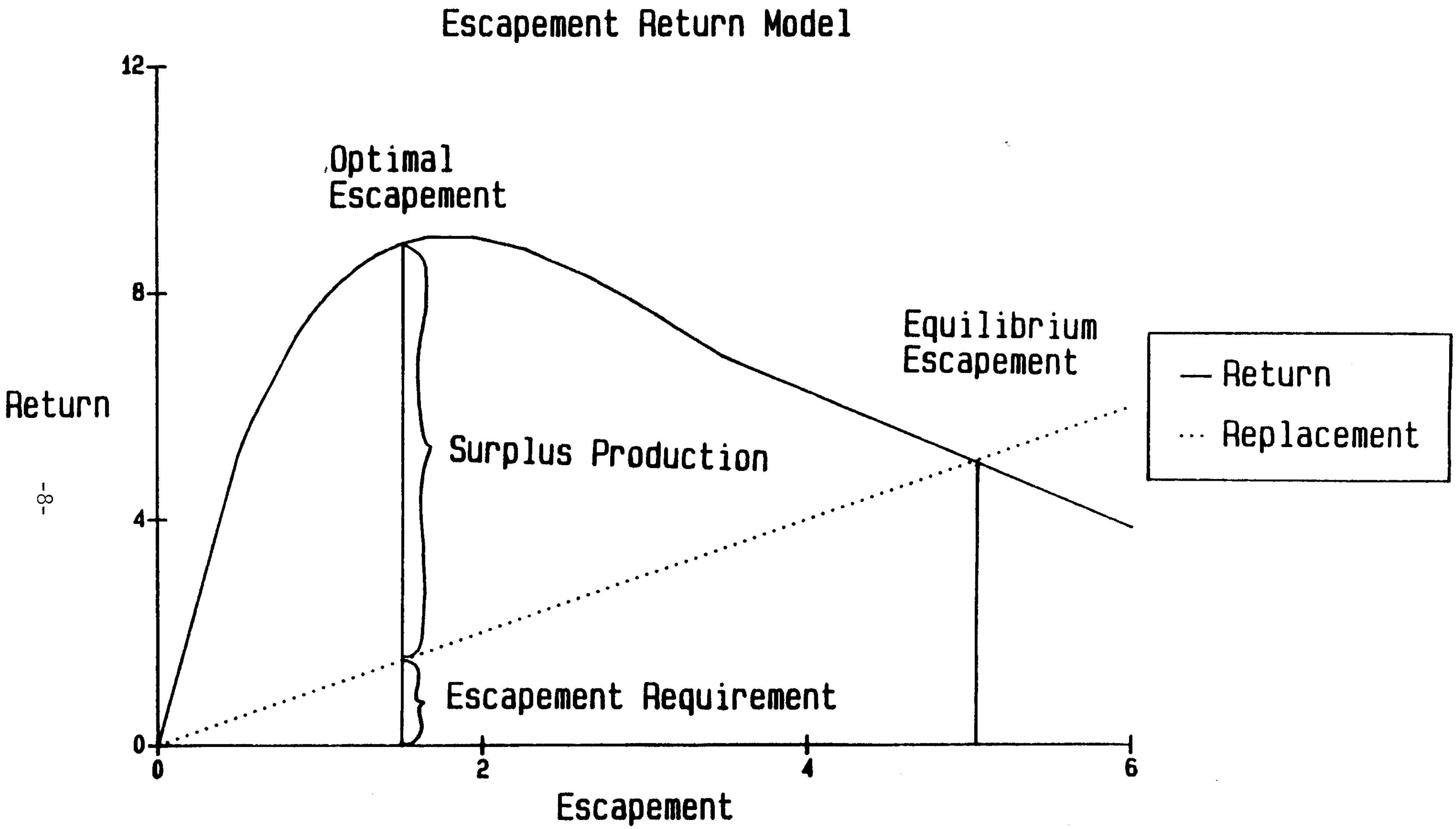

Figure 4. Idealized Ricker-type compensatory escapement-return model.

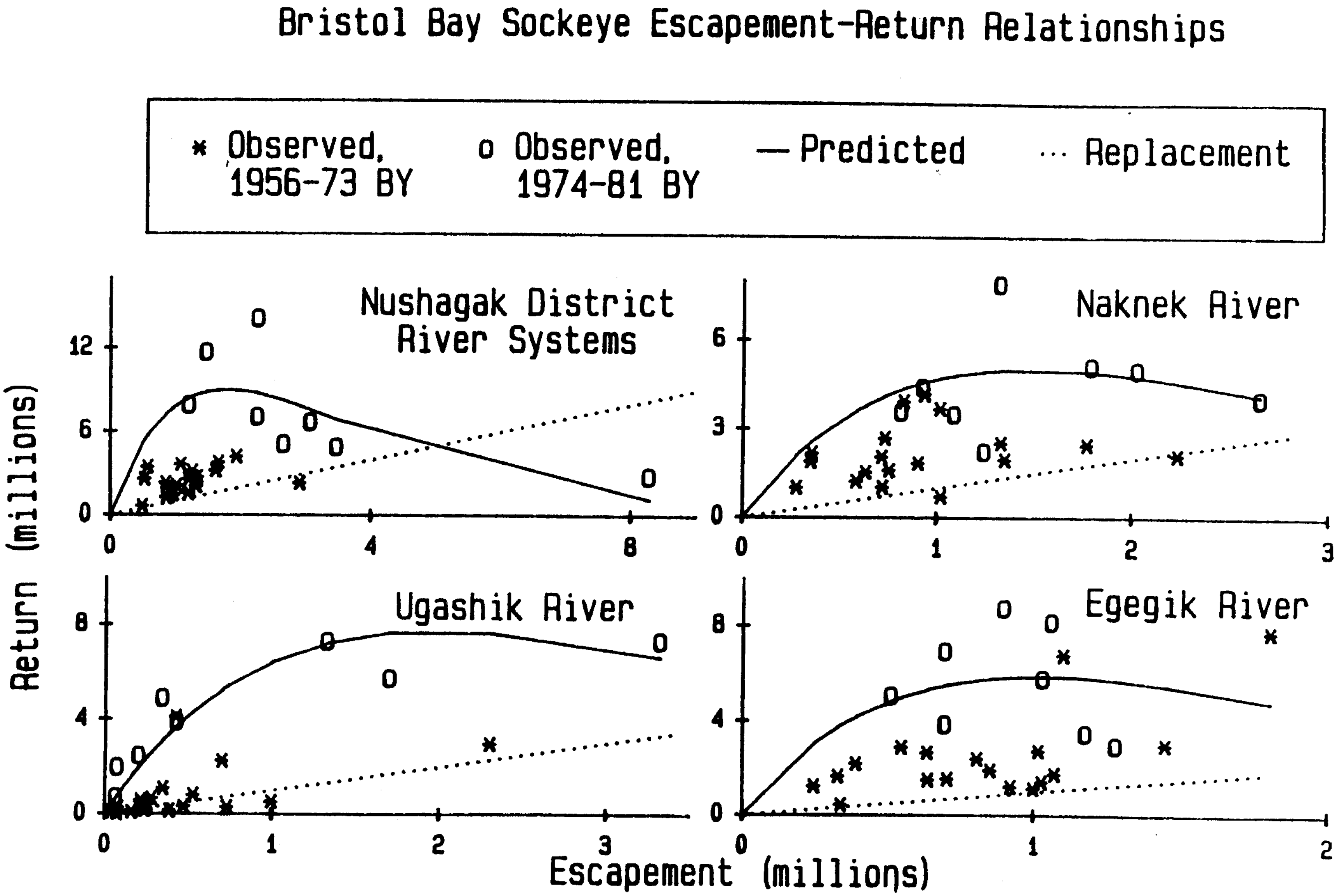

Figure 5. Escapement-return models for various Bristol Bay river systems. Shown are the observed data and model estimated from the recent (1974-1981 brood years) data.

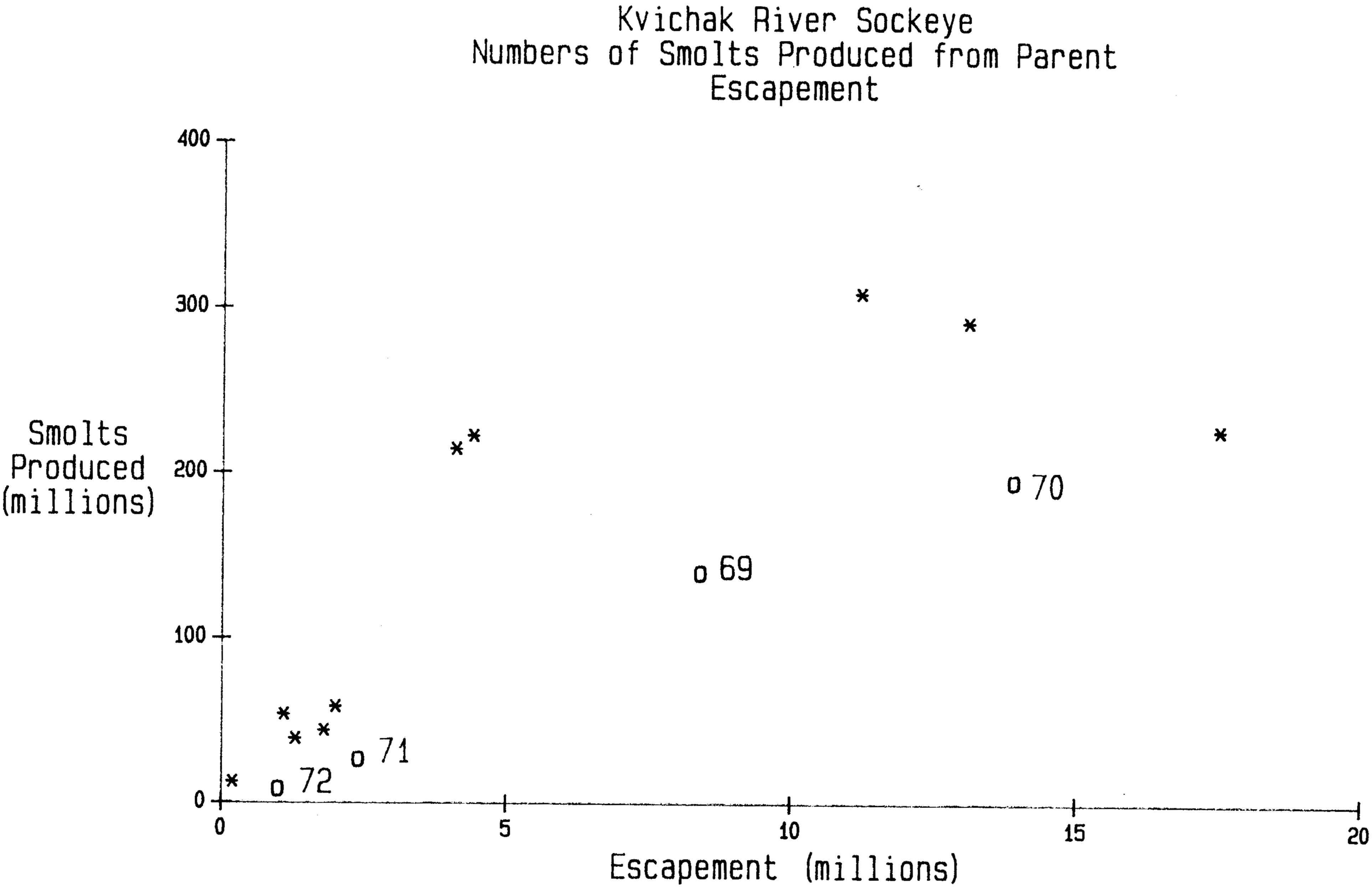

Figure 6. Estimated numbers of outmigrating sockeye salmon smolts plotted against parent escapement, 1969-82 brood years, for the Kvichak River (asterisks denote brood years 1973-82).

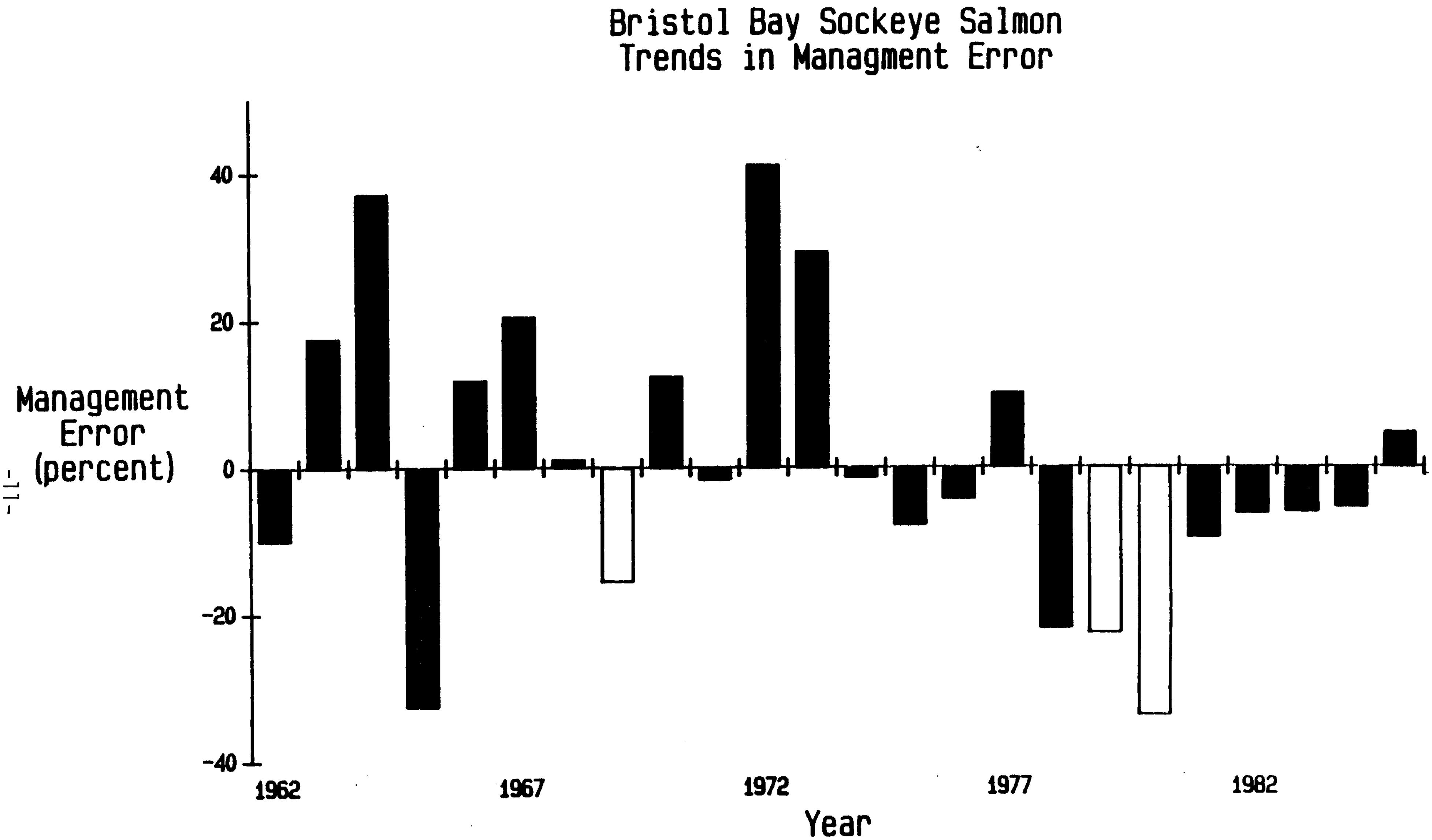

Figure 7. Bristol Bay management error expressed in difference in rate of exploitation necessary to achieve escapement goals and the actual rate of exploitation. Error is positive when the actual escapement is less than the goal and negative when escapement is greater than goal.

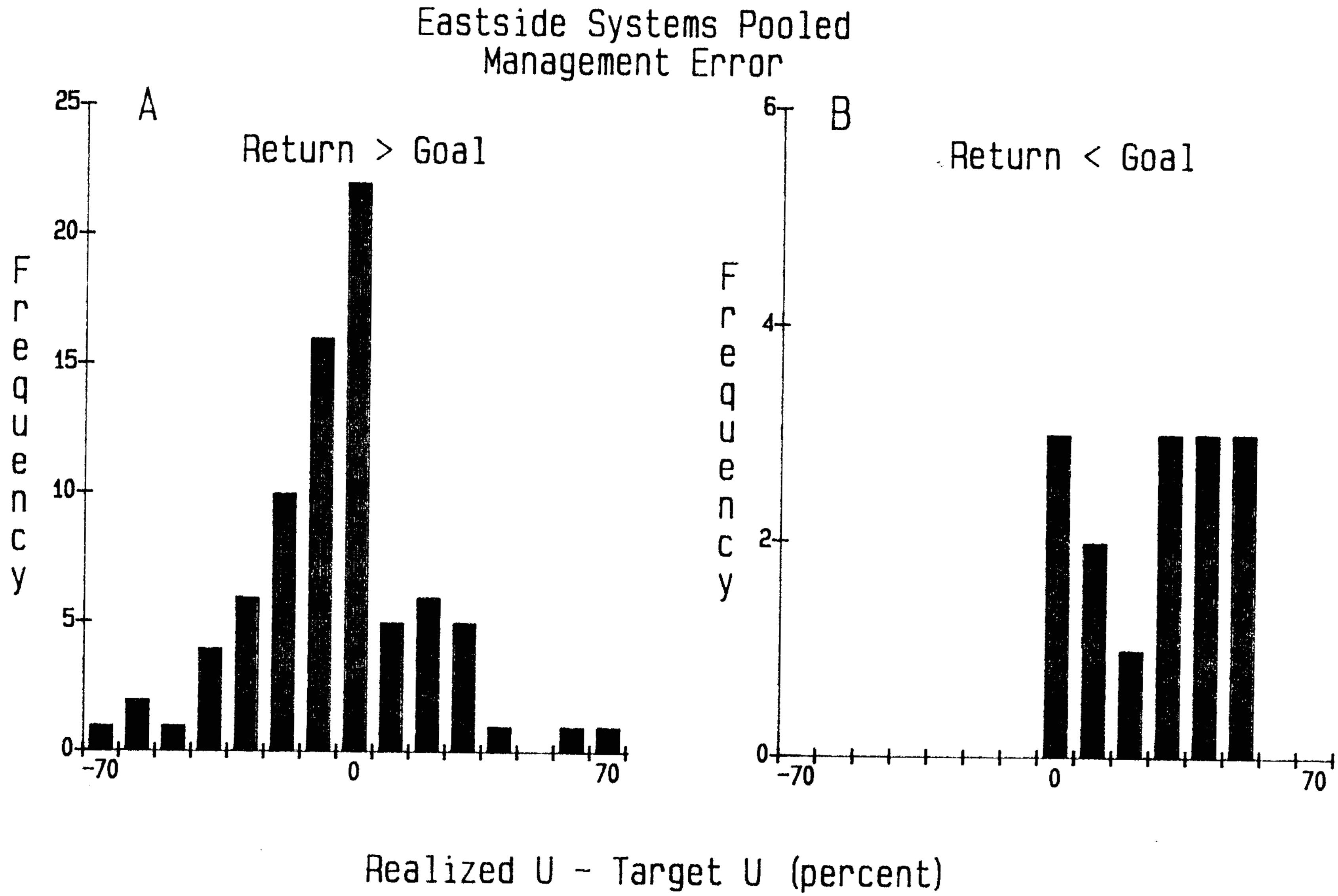

Figure 8. Frequency distribution of management error for all eastside Bristol Bay river systems pooled over 1962-85 return years. A, years where return was greater than escapement goal, and B, years where return was less than escapement goal.

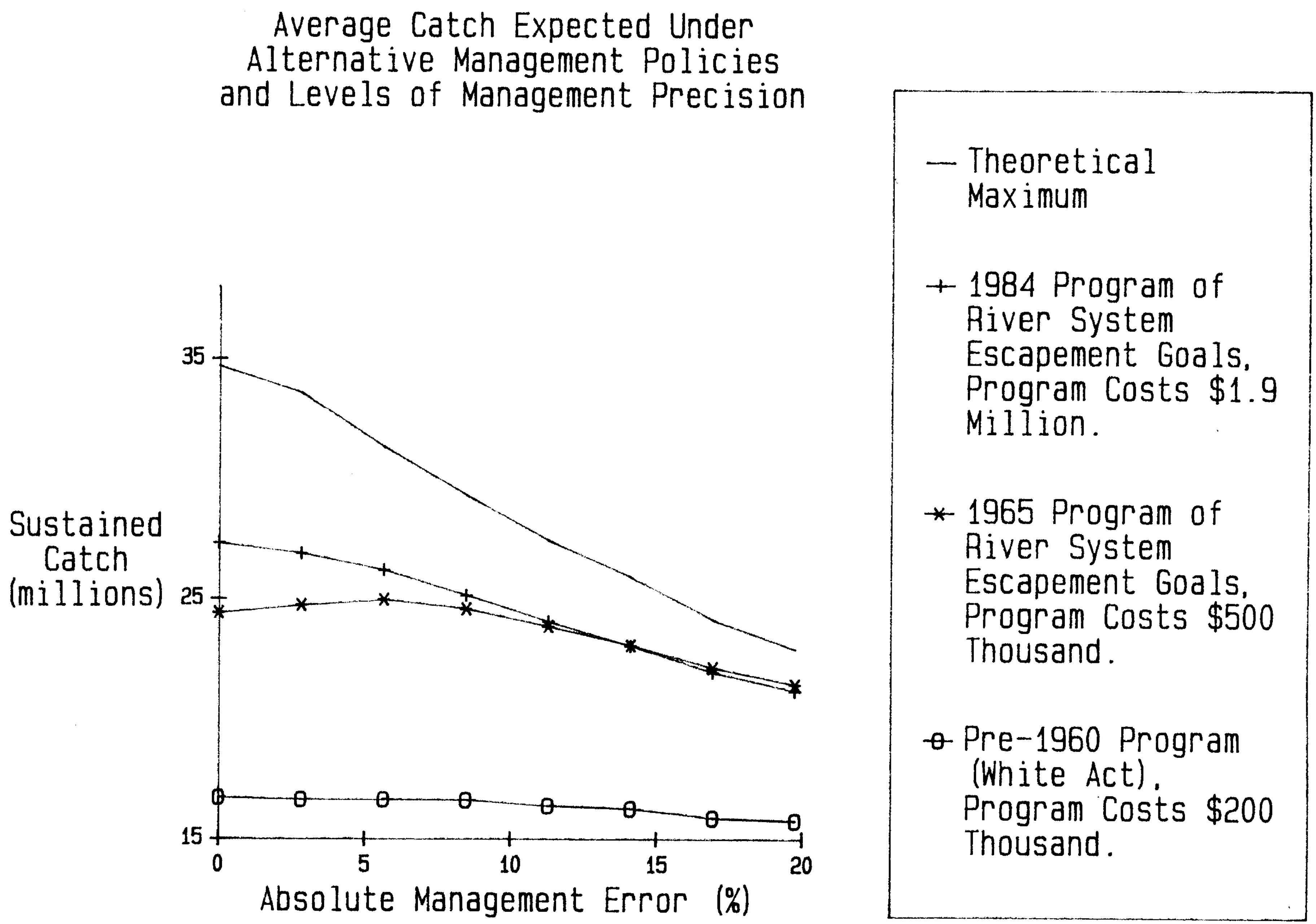

Figure 9. Results of the computer simulation of long term average catch expected under different management policies and levels of management error.

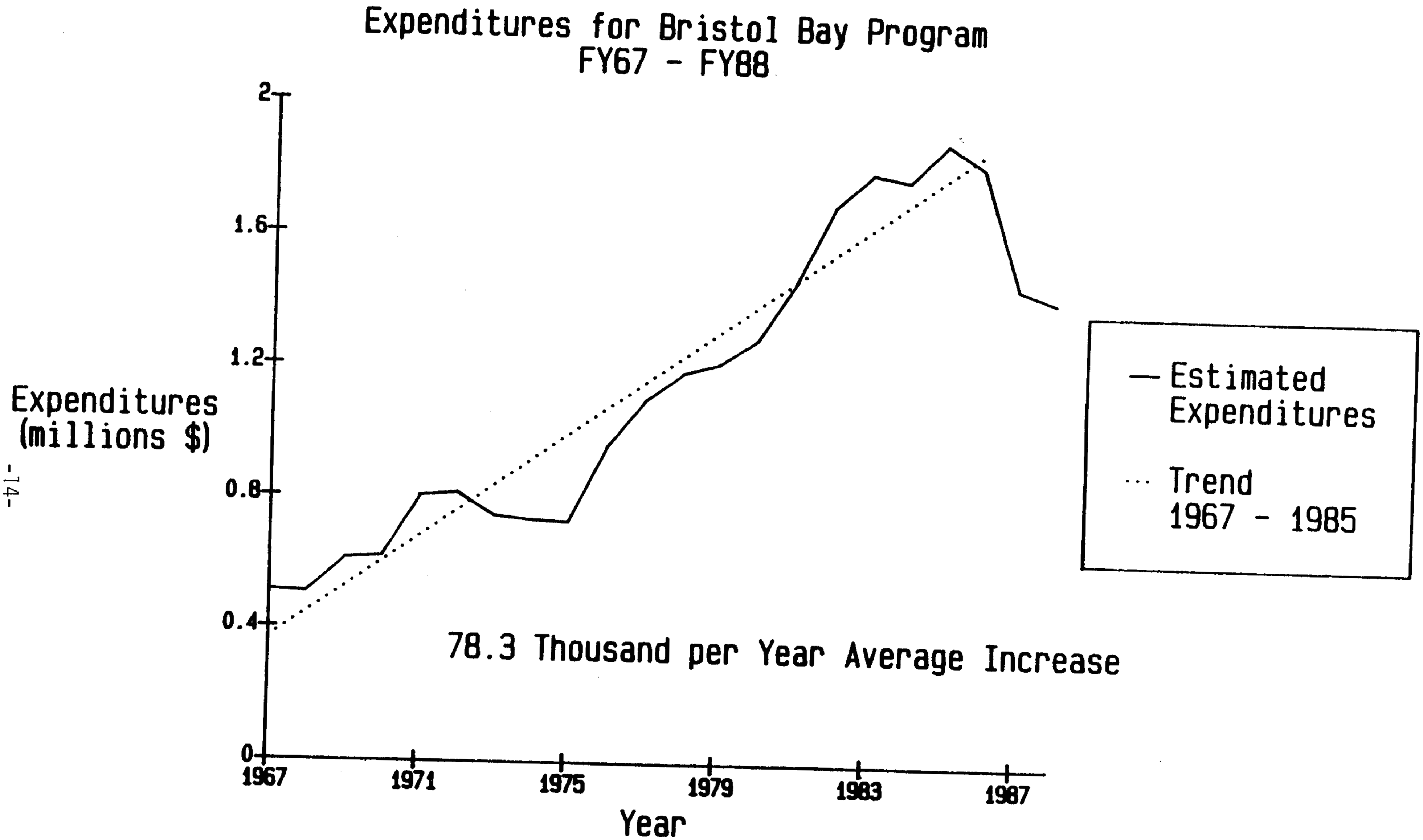

Figure 10. Expenditures for Bristol Bay management and research 1967 to 1987, together with increasing trend 1967-1987, together with increasing trend line and average $78.3 thousand per year increase in expenditures.

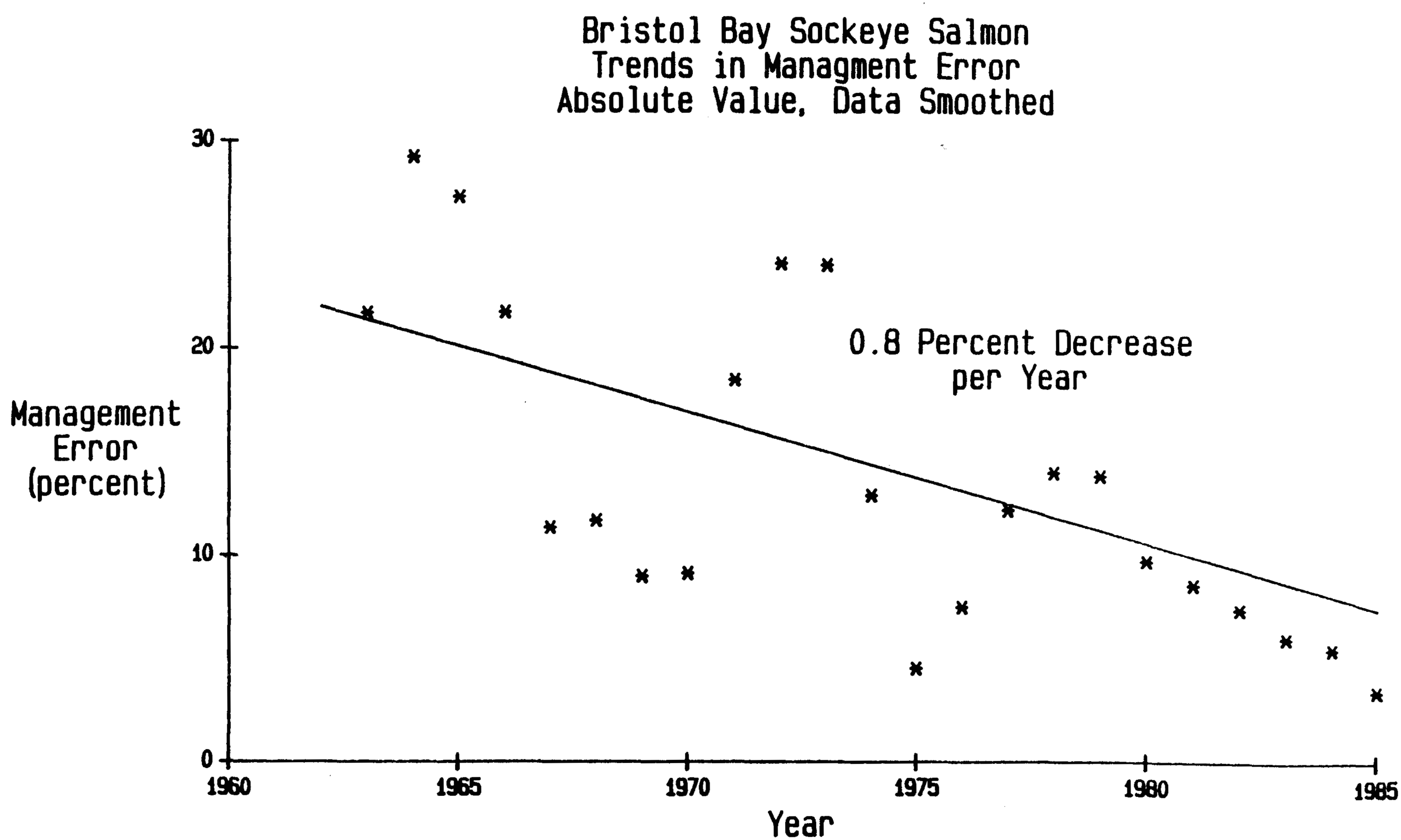

Figure 11. Trend in Bristol Bay management error, 1962-1985. Management error is expressed without regard to sign (i.e., positive or negative), and has decreased on the average of 0.8 percent per year.

Table 1. Historical narrative of changes in Bristol Bay management policy, growth of ADF&G program elements, increases in management precision, and increases in level of funding.

Year Policy Enacted	Policy	Additional Program Elements	Level of Management Precision (% Absolute Error)	Level of Funding 86 $$ (millions)
Before Statehood	White Act, 50% rate of exploitation	Mimimal	>25 %	minimal
1960	Fixed escapement goals goals preliminary	Local Management Catch and escapement enumeration Catch and escapement sampling Inseason Aerial Surveys	25%	0.2 *
1965	Fixed escapement goals formal goals cyclic Kvichak goals	Formal preseason forecast	21%	0.5 *
1984	Fixed escapement goals goals revised review of Kvichak policy	Inside and offshore testfishing Smolt enumeration Nushagak Sonar	7%	1.9
1987	Fixed escapement goals fixed Kvichak goals	Inseason Stock Identification Run strength from S. Pen. fishery Cut Port Moller testfishing Cut Naknek smolt	???	1.6

* very rough estimate

ECONOMIC IMPORTANCE OF ALASKA'S COMMERCIAL FISHERIES[1]

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ABSTRACT

The purpose of this report is to present a broad overview of the economic importance of Alaska's commercial fisheries. Domestic landings from marine fisheries off Alaska have nearly doubled in the last decade, from approximately 613 million lbs in 1976 to 1.2 billion lbs in 1985. The exvessel value of these landings have nearly increased five fold from $241 million in 1976 to $1.1 billion in 1987. Alaska is the leading west coast state for landings (pounds and exvessel value) from marine fisheries.

The year 1984 offered the most up-to-date and complete estimates of personal income and employment from commercial fishing in Alaska. In that year $509 million were paid to fishermen for landings into Alaskan ports, and gross receipts paid to Alaska seafood processors totalled more than $1 billion. The harvest and processing of these seafood products resulted in personal income of $583 million to all workers in Alaska of which $431 million went to Alaska residents.

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[1]This document is a written version of an oral presentation by the senior author at the annual meeting of the Alaska Chapter of the American Fisheries Society held during November 14-17, 1988 in Juneau. While some of the data presented here are new, much of this information was cited from two published reports: Kruse (1988) and Berman and Hull (1987). Interested readers are referred to both earlier reports for more detail; copies are available from ADF&G, Division of Commercial Fisheries, Publications Section, P.O. Box 3-2000, Juneau, AK 99802-2000.

This included $239 million to harvesters (57% or $136 million to Alaska residents), $104 million to processing employees (53% or $55 million to residents), $210 million to Alaskan residents employed in indirect and induced activities (e.g., service industries, transportation, etc.), and approximately $30 million in taxes related to the commercial fishing industry. In 1984, the total direct, indirect and induced earnings from the commercial fishing industry totalled approximately 27% of the total personal income generated by the private sector. Commercial fishing was most important to the southwest region of the state where it generated 47% of the total regional income or 98% of the total personal income by private basic sector activity. More than 48,000 resident and non-resident employees derive most of their wages from harvesting and processing fish and shellfish caught in commercial fisheries in Alaska.

Unfortunately, similar estimates of personal income resulting from commercial fishing are unavailable since 1984. However, it is known that exvessel value has nearly doubled over three years since 1984 to $1.1 billion in 1987. In 1987 six Alaska ports were in the top 25 nationally based upon exvessel value of landings. Because of these increases in fishing activity and recent declines in both earnings of the oil industry and expenditures by state government, the estimated percentage of personal income in Alaska associated with the commercial fishing industry has undoubtedly increased well above previously documented levels of 1984.

LANDINGS AND EXVESSEL VALUE OF ALASKA'S COMMERCIAL FISHERIES

The purpose of this report is to provide a broad overview of the economic importance of commercial fisheries in the state of Alaska. We begin our discussion with an examination of the domestic landings (excluding joint venture and foreign fisheries) of major species groups caught off the coast of Alaska (Table 1, Figure 1). Total domestic landings from marine fisheries off Alaska nearly doubled over 1976-85. Of the 1.2 billion pounds landed in 1985, salmon constituted 56%, groundfish comprised 20%, herring and shellfish were 10% each, and halibut was 4%. The exvessel value (dollars paid to fishermen or gross receipts) of these major species groups increased nearly three fold over 1976-85 or nearly five fold over 1976-87 (Table 2, Figure 2). Exvessel value nearly doubled from 1984 to 1987 alone. Salmon comprised 42% of the $1.1 billion exvessel value in 1987; groundfish were 29%, shellfish comprised 19%, halibut was 5%, and herring accounted for 4%.

Of the $1.1 billion in exvessel value for 1987, 84% or $942 million in fish and shellfish were delivered to Alaskan ports (NMFS 1988). Six Alaskan ports accounted for approximately one-third of the total exvessel value of landings into Alaska. Kodiak was the leading Alaska port with $132.1 million in exvessel value, Dutch Harbor-Unalaska was second with $62.7 million, followed by Cordova at $41.9 million, Petersburg with $36.9 million, $33.6 million was landed into Sitka, and Ketchikan was sixth with $22.8 million. All six of these Alaskan ports were in the top 25 nationally for exvessel value of landed fish and shellfish. Kodiak was second nationally behind New Bedford (Massachusetts), Dutch Harbor-Unalaska was forth, Cordova ninth, Petersburg tenth, Sitka 15th, and Ketchikan was 24th. Some major cities that are commonly perceived as dominant fishing ports actually ranked behind these six Alaska towns, including Seattle (29th), Boston (34th) and San Francisco (48th).

COMPARISON OF LANDINGS AMONG WEST COAST STATES

Alaska is the leading west coast state for landings from commercial marine fisheries (Table 3, Figure 3). In 1986 landings into Alaska (by weight) were more than triple the landings into California, which was second among west coast states. Landings data differ from catch data, because catches off one state may be landed into other states. For example, a significant percentage of landings into Washington and Oregon are fish and shellfish caught off the coast of Alaska. Additionally, significant foreign catches of tuna by U.S. vessels are landed into California. The disparity between Alaska and other west coast states is somewhat greater in terms of exvessel value than for landings in weight (Table 3, Figure 4). For example, landings into Alaska were worth nearly 5.5 times more exvessel value than those into California for 1986.

Three major species groups account for much of the difference in landings between Alaska, Washington, Oregon and California. Commercial catches of salmon along the west coast of the United States are dominated by landings into Alaska (Table 4, Figure 5). In 1985 landings of salmon into Alaska were nearly 16 times greater than those into Washington, and landings into Washington were nine times greater than those into California and Oregon combined.

Although reduced from catch levels in the late 1970's, Alaska is the west coast leader of shellfish landings (Table 5, Figure 6). In 1985 landings of crabs and shrimp into Alaska were nearly six fold greater than those landed into Oregon, which was second among west coast states. The exvessel value of shellfish caught off Alaska has been increasing since 1984 (Table 2).

Historical groundfish landings provide an interesting contrast to salmon and shellfish. In 1976 only 1 million lbs of groundfish were landed into Alaska (Table 6, Figure 7). Since then, landings have grown to 233.1 million lbs in 1985, but fell to 194.8 million lbs in 1986. Landings in 1986 were slightly more than double the landings of groundfish into California. This striking increase in groundfish landings into Alaska over the last decade is dwarfed by the growth in joint venture catches of groundfish (Table 6, Figure 8). In fact, 88% of all west coast catches of groundfish in 1988 were attributed to joint venture fisheries. Most joint venture catches of groundfish are taken off the coast of Alaska. Since 1980, groundfish catches off the Alaska coast (as indexed by joint ventures catches plus domestic landings into Alaska) greatly exceed landings into all other west coast states combined (Figure 8). In 1986 domestic landings into Alaska plus joint venture catches exceeded the sum of all groundfish landings into Washington, Oregon, and California by 16 fold. This is the case, despite the fact that landings of groundfish caught off Alaska but landed into these other states have not been removed from these figures.

ECONOMIC IMPACTS OF COMMERCIAL FISHERIES ON ALASKA'S ECONOMY: PERSONAL INCOME AND EMPLOYMENT

What is the economic impact of commercial fisheries in Alaska? **Economic impact** refers to the economic activity generated by the use of the resource. Typically, economists refer to economic impacts in terms of personal income and employment. They may also refer to economic impacts in terms of direct effects, indirect effects, and induced effects on personal income or employment. These terms will be defined later as they are introduced to our discussion. For the balance of this report, we focussed mainly upon personal income and to a lesser extent upon employment.

Due to analyses by Berman and Hull (1987), the best estimates of the economic impact of the commercial fishing industry in Alaska exist for 1984. Recall that there were 983.7 million lbs of fish and shellfish caught off Alaska in 1984 (Table 1) worth $597.1 million in exvessel value (Table 2). Of this total, 85% or $509.3 million (Table 3) in exvessel value was landed in Alaska. These landings resulted in wholesale value (gross receipts to processors) of $1.044 billion (ADF&G 1986). Using economic data and a model, Berman and Hull (1987) estimated that harvesting, processing, and other economic activity associated with the commercial fishing industry in Alaska resulted in $583 million in personal income in 1984. About 74% or $431 million of this total was earned by Alaska residents. Personal income associated with the fishing industry accounted for 7% of the total personal income earned statewide or 27% of the total private basic income (excluding government expenditures) in Alaska in 1984.

A regional breakdown of personal income earned in Alaska yields insight into the importance of commercial fishing around the state (Table 7). Berman and Hull (1987) found it most convenient to estimate regional income for regions as defined by the Alaska Department of Labor. The six regions are defined as follows (see Berman and Hull 1987 for more complete descriptions). The southwest region includes the Aleutian Islands, Bethel, Bristol Bay Borough, and Dillingham. The gulf coast region includes the Kenai Peninsula, Kodiak Island, and the Cordova-Valdez areas. The interior region consists of the area near Fairbanks. "Anchorage-Mat-Su" includes the area comprising the city of Anchorage and the Matanuska-Susitna Borough. The northern region includes Nome, Kobuk, and the North Slope, and "Southeast" includes all of Southeast Alaska.

Nearly 42% ($242 million) of the $583 million in personal income was earned in the southwest region of Alaska (Table 7). This accounted for 48% of the total personal income earned in this region or 98% of the total private basic income earned in the southwest region. Personal income earned as a result of commercial fishing activity also accounted for very significant percentages of private basic income in the gulf coast region (44%) and in Southeast Alaska (40%). Even in the industrial center of Alaska (Anchorage), commercial fishing resulted in 9% of the total personal income earned in the private sector.

Earlier we mentioned that we can also discuss economic impacts on personal income in terms of direct effects, indirect effects, and induced effects (Berman and Hull 1987). In 1984 total direct effects of the commercial fishing industry on personal income in Alaska totalled $269 million, forward indirect effects accounted for $104 million, and $210 million were attributed to other indirect and induced effects. Personal income associated with **direct effects** include income earned by vessel owners, skippers, and crew. In short, direct effects include the harvesting sector. Of the $269 million in direct effects, $136 million were associated with Alaska residents, $103 million was earned by nonresidents, and $30 million was attributed to taxes. Personal income associated with **forward indirect effects** include income earned through warehousing, distribution, purchases by processors, cold storage facilities, tender vessels, canneries, etc. In other words, forward indirect effects include income associated with seafood processing. Of the $104 million in personal income related to forward indirect effects, $55 million was earned by residents and $49 million was earned by non-residents. **Other indirect effects** are also named **backward indirect effects**. These include income earned as a result of expenditures of income from direct and indirect effects. Income from **induced effects** include fishermen's purchases of oil, fuel, and supplies, vessel repair, and other business purchases by fishermen. Berman and Hull (1987) estimated only resident income ($210 million) associated with other indirect and induced effects.

Economic impacts can also be expressed in terms of employment. Unfortunately, there is insufficient time to allow a full discussion of employment associated with the commercial fishing industry. Briefly, we wish to point out that there are a number of statistics that one could examine concerning employment and there are difficulties with each of them. These difficulties are particularly acute for fish harvesting and seafood processing sectors of the economy. Some of the problems are discussed more thoroughly elsewhere (Berman and Hull 1987, Focht 1986, Kruse 1988). We can consider **employment**, which is the average number of jobs over a certain time period. We could also consider **employees**, which is the number of unique individuals working in the industry. Additionally, there are proxy statistics, such as number of **vessel licenses**, **fishing permits**, **individuals purchasing permits**, and **crew member licenses**.

Statistics on employment, employees, and participation in commercial fisheries in Alaska for 1984 are summarized in table 8. Just as an example, if we examine the number of employees, we see that 29,604 employees earned their income from fish harvesting in Alaska. Of these, 75% or 22,123 were Alaskan residents. Accounting problems exist for these estimates (Focht 1986), and these figures cited here are "unofficial". Likewise, processing employees totalled 18,683 individuals; 65% or 12,068 were Alaska residents. These statistics relate to the number of unique individuals who earned most of their annual wages in this industry (Jensvold et al. 1987). Thus, these figures underestimate the total number of persons who earned income from seafood processing. The Alaska Department of Labor now tallies the total number of unique individuals who earned income in seafood processing (Brynn et al. 1988).

Enough about 1984. What is the economic impact of commercial fisheries on Alaska's economy now? Unfortunately, an update of the analyses by Berman and Hull (1987) have not been conducted. However, we do know that the exvessel value of fish and shellfish caught off Alaska have almost doubled from $597 million in 1984 to $1.1 billion in 1987 (Table 2). Over these three years the exvessel value of shellfish doubled, herring and halibut more than doubled, and groundfish tripled. While data are not yet complete, we know that the exvessel value of salmon and herring increased more than 50% and 20%, respectively, from 1987 to 1988 alone. Clearly, there must be similar significant increases in personal income and employment associated with the commercial fishing industry in Alaska since 1984. Additionally, because oil revenues have been declining over the past few years, there must be a further compounding of the relative importance of commercial fishing to the economy overall. That is, aside from the dramatic increases in exvessel value of Alaskan fish and shellfish, the percentage of regional and statewide incomes associated with commercial fishing must have increased simply due to declining incomes and employment associated with the oil industry. Commercial fishing has become a more dominant component of Alaska's economy since 1984.

Lastly, we wish to point out the magnitude of the task which confronts the Alaska Department of Fish and Game in its attempt to manage these extremely valuable fishery resources. We compared estimates of the expenditures on fishery management by management agencies of west coast states for fiscal year 1986 with the exvessel value of landings into those states for calendar year 1986 (Kruse 1988). Total annual expenditures by Alaska, Washington, Oregon, and California were approximately $54.2, $47.7, $38.3, and $68.5 million, respectively. The expenditures on fishery management as a percentage of exvessel value for these same states were 7.6%, 51.3%, 83.4%, and 51.5%. The discrepancy for Alaska is obvious, and the percentage appears to be declining further due to increases in exvessel value and budget reductions. It should be pointed out that these comparisons did not include the "value" of sport fisheries, habitat improvements, and other benefits of fishery expenditures are excluded from the comparisons. Comparison of exvessel value of landings is also somewhat misleading, because some catches off Alaska are actually landed into the other west coast states, and state agencies are not responsible for management of all fisheries from which landings are made. Other fishery management agencies include the North Pacific Fishery Management Council, Pacific Fishery Management Council, Pacific Salmon Commission, United States Forest Service, etc. Their expenditures are not included. Despite these difficulties, it is clear to us that ADF&G is substantially under-funded relative to other west coast states with respect to the value of resources managed. We also suspect that increased investment in management could improve the value of Alaska's fisheries well beyond current levels.

CONCLUSIONS

We would like to leave you with the following conclusions. In 1984 the exvessel value of fish and shellfish caught off Alaska was $597.1 million. This was associated with over $1 billion in gross receipts to seafood processors. Personal income associated with the commercial fishing industry in Alaska was $583 million. This equalled 27% of the total private sector income for the state of Alaska in 1984. More than 48,000 employees derived their primary source of income from harvesting and processing alone.

In 1987 six Alaska ports were in the top 25 nationally based upon exvessel value of the landings. The total exvessel value of fish and shellfish caught off Alaska exceeded $1.1 billion. This was almost double the exvessel value just three years earlier in 1984. There must have been a corresponding increase in personal income and employment associated with this growth. Declining oil revenues and restrictions in spending by state government has compounded these increases in the percentage of personal income and employment attributable to the commercial fishing industry in the state. In short, the marine fishery resources off its coast are extremely valuable to Alaska.

ACKNOWLEDGMENTS

The authors thank a number of people for their contributions to this document. Kathy Thomas of the Alaska Department of Labor provided information on employment in seafood processing, Kurt Schelle of the Commercial Fisheries Entry Commission contributed data on vessel licenses and fishing permits, Herman Savikko of the Division of Commercial Fisheries provided preliminary data on exvessel value of Alaska's fisheries for 1988, and Phil Rigby and Doug Eggers also of the Division of Commercial Fisheries were helpful with data acquisition and suggestions about presentation. Matt Berman of the Institute of Social and Economic Research of the University of Alaska - Anchorage conducted an extremely valuable study on the commercial fishing industry in Alaska which we cited heavily in this document. Lastly, we are very grateful to Jeff Hartman of the Division of Fisheries, Rehabilitation, Enhancement and Development who was instrumental in the development and review of the contract which led to the study by Berman and Hull (1987), thorough review of multiple drafts of Kruse (1988), review of this document, and his encouragement and insights.

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NMFS (National Marine Fisheries Service). 1988. Fisheries of the United States, 1987. National Marine Fisheries Service, Current Fisheries Statistics 8700, Washington, DC.

Table 1. Domestic landings (in millions of pounds) of major species groups caught off Alaska.

Species Group	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Salmon[a]	245.9	307.4	389.7	442.7	511.4	612.0	562.7	621.3	660.5	673.1
Shellfish[a]	317.7	316.3	334.0	344.8	370.1	236.2	147.0	110.9	91.5	119.6
Halibut[a]	14.8	12.4	13.0	15.1	11.4	16.8	20.4	29.1	35.5	45.2
Herring[a]	33.4	31.9	36.0	60.6	84.3	96.3	104.3	108.3	97.7	120.8
Groundfish[b]	1.0	2.5	5.8	10.0	18.1	43.7	60.9	90.4	98.5	233.1
Total	612.8	670.5	778.5	873.2	995.3	1005.0	895.3	960.0	983.7	1191.8

[a]Source: ADF&G (Alaska Department of Fish and Game). 1986. Alaska 1985 catch and production. Alaska Department of Fish and Game, Division of Commercial Fisheries, Statistical Leaflet 38, Juneau.

[b]Source: Pacific Marine Fisheries Commission Annual Reports, 1977-88. Catches by foreign vessels, joint venture catches, and landings into other states are not included in these groundfish data.

Table 2. Exvessel value (in millions of dollars) of commercial catches of major species groups caught off Alaska.[a]

Species Group	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986[b]	1987[b]	1988[b]
Salmon	119.7	176.4	241.2	346.8	254.1	397.3	309.7	320.2	343.1	389.6	414.0	473.0	734.6[c]
Shellfish	97.3	153.2	230.6	239.0	265.3	196.9	211.7	146.6	102.1	106.4	182.0	213.5	N/A
Halibut	20.5	17.6	23.4	32.9	13.5	19.3	24.9	35.3	24.9	40.3	79.4	60.9	N/A
Herring	2.5	2.7	7.2	32.7	12.2	18.6	20.2	28.9	19.8	36.9	38.5	42.7	51.4[c]
Groundfish	1.1	1.6	3.3	6.3	8.9	24.0	40.9	78.0[d]	107.2[d]	137.5[d]	197.9[d]	330.5[d]	N/A
Total	241.1	351.5	505.7	657.7	554.0	656.1	607.4	609.0	597.1	710.7	911.8	1120.6	N/A

[a]Compiled November 30, 1988.

[b]The estimates for 1986-88 are preliminary.

[c]Herman Savikko, ADF&G, Division of Commercial Fisheries, Juneau, personal communication.

[d]1983-87 groundfish include JV and DAP landings in and out of Alaska.

Table 3. United States commercial fisheries landings (millions of pounds, millions of dollars) for the Pacific Coast states.[a]

	Alaska		Washington		Oregon		California	
Year	Weight	Value	Weight	Value	Weight	Value	Weight	Value
1976	616.4	227.2	131.3	80.9	98.9	48.7	896.9	185.6
1977	644.0	326.2	146.1	80.8	112.5	48.5	874.4	195.0
1978	745.6	438.6	138.3	97.2	134.7	56.6	722.3	228.2
1979	898.5	597.0	170.0	116.0	127.8	65.2	728.4	227.5
1980	1053.9	560.6	155.8	85.5	126.3	55.7	804.3	323.4
1981	975.2	639.8	184.6	96.0	134.6	52.5	775.2	275.2
1982	878.9	575.6	170.2	90.1	127.6	57.5	695.4	241.2
1983	963.8	543.9	150.0	61.3	96.7	38.5	528.9	202.0
1984	1002.9	509.3	156.3	75.7	82.5	33.6	459.2	176.6
1985	1184.8	590.8	167.5	93.0	101.3	45.9	362.8	132.9
1986	1236.1	752.4	186.8	111.3	113.4	62.4	386.7	139.2

[a]Source: National Marine Fisheries Service. 1976-87. Fisheries of the United States, 1976-86. Current Fisheries Statistics 7200, 7500, 7800, 8000, 8100, 8200, 8300, 8320, 8360, 8385.

Table 4. Commercial landings (thousands of fish) of salmon along the Pacific Coast of the United States for 1973-85.[a]

Year	Alaska	Washington	Oregon	California
1973	22,319	7,446	1,159	1,165
1974	21,886	4,621	1,361	1,148
1975	26,229	4,999	882	783
1976	44,423	3,611	2,011	1,162
1977	46,405	6,009	786	598
1978	78,695	4,139	804	757
1979	86,559	7,079	1,149	823
1980	110,283	3,526	748	625
1981	111,425	7,687	854	627
1982	110,082	6,068	1,102	854
1983	127,159	4,236	435	331
1984	132,246	4,122	283	334
1985[b]	146,845	9,232	619	378

[a]Source: Seafood Business Report. 1985. Vol. 4. No. 2.

[b]Preliminary figures for 1985.

Table 5. Shellfish[a] landings (millions of pounds) into Pacific Coast states for 1976-85.[b]

	Landings by State			
Year	Alaska	Washington	Oregon	California
1976	317.2	19.1	34.6	20.9
1977	316.2	25.4	64.8	42.1
1978	334.0	21.5	69.2	27.1
1979	337.3	20.1	46.0	13.1
1980	364.7	19.2	48.5	17.9
1981	238.5	12.8	35.4	16.0
1982	143.1	7.6	27.3	14.8
1983	106.3	12.5	10.8	6.3
1984	86.1	8.3	9.5	6.9
1985	115.5	13.8	19.7	7.7

[a]Tanner crab, king crab, Dungeness crab and shrimp only.

[b]Source: Seafood Business Report, March/April 1986. Vol. 5 No. 2. King crab, Tanner crab and shrimp landings were tabulated by calendar year. Dungeness crab landings were tabulated by fishing season. Here, data for the 1975-76 fishing season for Dungeness crabs were summarized with data for the other species from 1976. The same association was done for the other years of data, as well.

Table 6. Commercial groundfish landings (millions of pounds) by state, joint ventures[a], and totals for the Pacific Coast of the United States over 1976-86.[a]

Year	Landings					
	Alaska	Washington	Oregon	California	Joint Ventures	U.S. Total
1976	1.0	47.8	25.0	64.1	0.0	137.8
1977	2.5	50.9	20.9	62.5	0.0	136.9
1978	5.8	58.9	31.8	64.0	0.0	160.6
1979	10.0	70.1	46.6	66.8	19.4	212.8
1980	18.1	81.8	77.5	76.5	306.9	560.8
1981	43.7	91.5	82.0	74.9	555.1	847.2
1982	60.9	95.3	90.2	113.5	556.9	916.8
1983	90.4	95.8	77.0	91.4	939.5	1,294.0
1984	98.5	100.0	62.3	89.4	1,438.0	1,788.1
1985	233.1	57.9	63.9	95.1	1,998.9	2,449.0
1986	194.8	45.2	54.7	84.2	2,864.2	3,243.2

[a]Most recent joint venture landings come from Alaskan waters.

[b]Source: Pacific Marine Fisheries Commission Annual Reports, 1977-88. Foreign landings are not included in these data.

Table 7. Estimated impact of commercial fishing on personal income in Alaska in 1984 by Berman and Hull (1987).

	Region						Alaska Statewide Total
	Anchorage Mat-Su	Southwest	Gulf Coast	Interior	Northern	Southeast	
Total Personal Income (millions)	$78	$242	$148	$1	$16	$99	$583
Resident Personal Income (millions)	$78	$161	$106	$1	$11	$73	$431
Percent of Regional Income	2%	47%	19%	<1%	2%	10%	7%
Percent of Private Basic Regional Income	9%	98%	44%	1%	5%	40%	27%

Table 8. Estimates of employment[a], number of employees[b] and other statistics[c] on participation in the commercial fishing industry in Alaska in 1984.

	Alaska Residents	Percent Alaskans	Total
Employment			
Harvesting			
Peak Monthly			26,000[d]
Average Annual			8,000[d]
Processing			
Peak Monthly			24,395
Average Annual			6,327[d]
Employees			
Harvesting	22,123	75%	29,604
Processing	12,068	65%	18,683
Other Statistics			
Vessels Licensed	11,794[e]	72%[e]	16,391
Fishing Permits	25,653	85%	30,284
Individuals Purchasing Permits	15,285	82%	18,629
Crew Member Licenses	16,929	65%	26,187

[a]Kathy Thomas, Alaska Department of Labor, Juneau, personal communication.

[b]Jensvold et al. (1987).

[c]Kurt Schelle, Commercial Fisheries Entry Commission, Juneau, personal communication.

[d]Data for 1983.

[e]An additional 1,998 vessels were licensed to individuals of unknown residency.

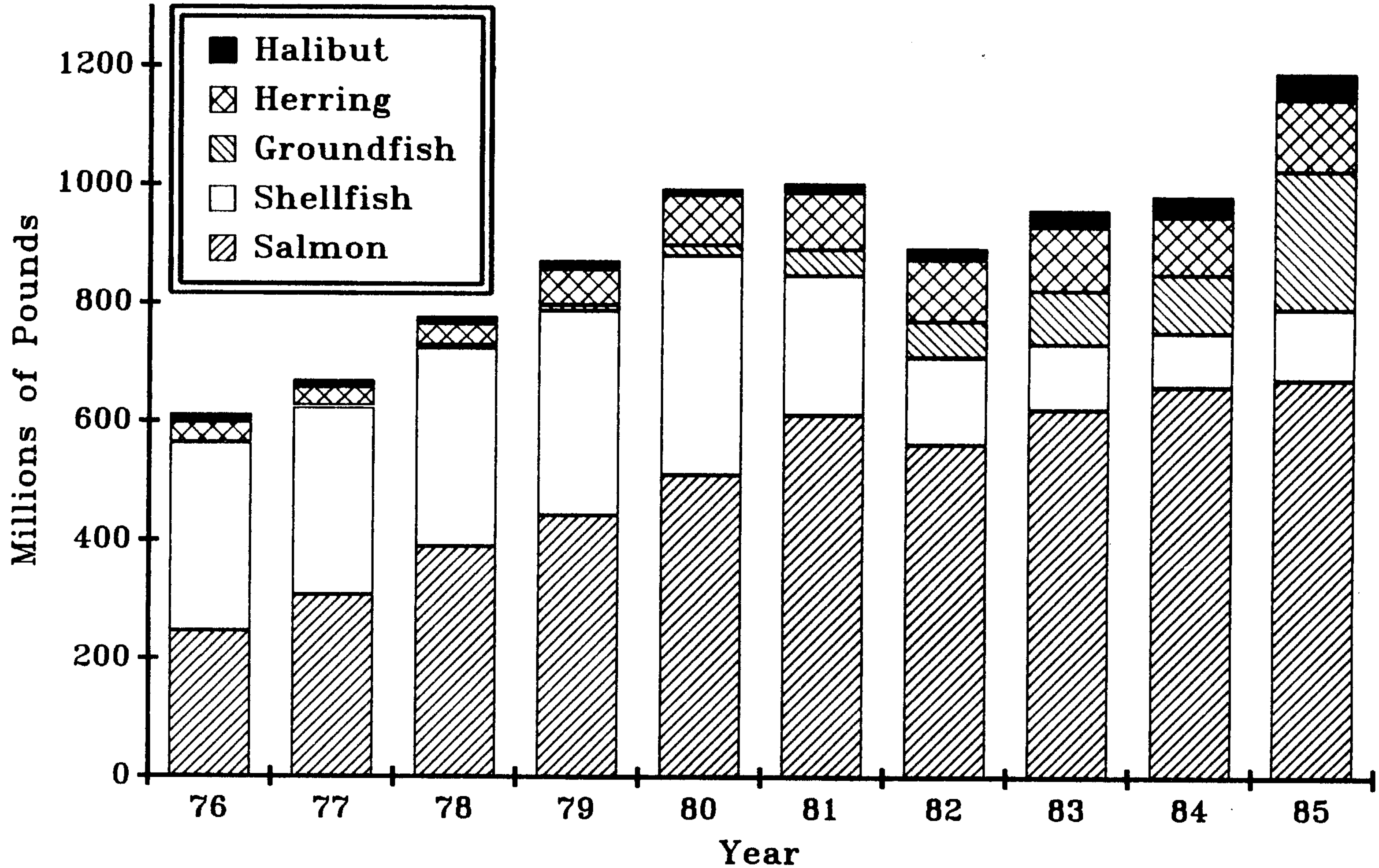

Figure 1. U.S. Domestic landings (in millions of pounds) of major species groups caught off Alaska in 1976-85.

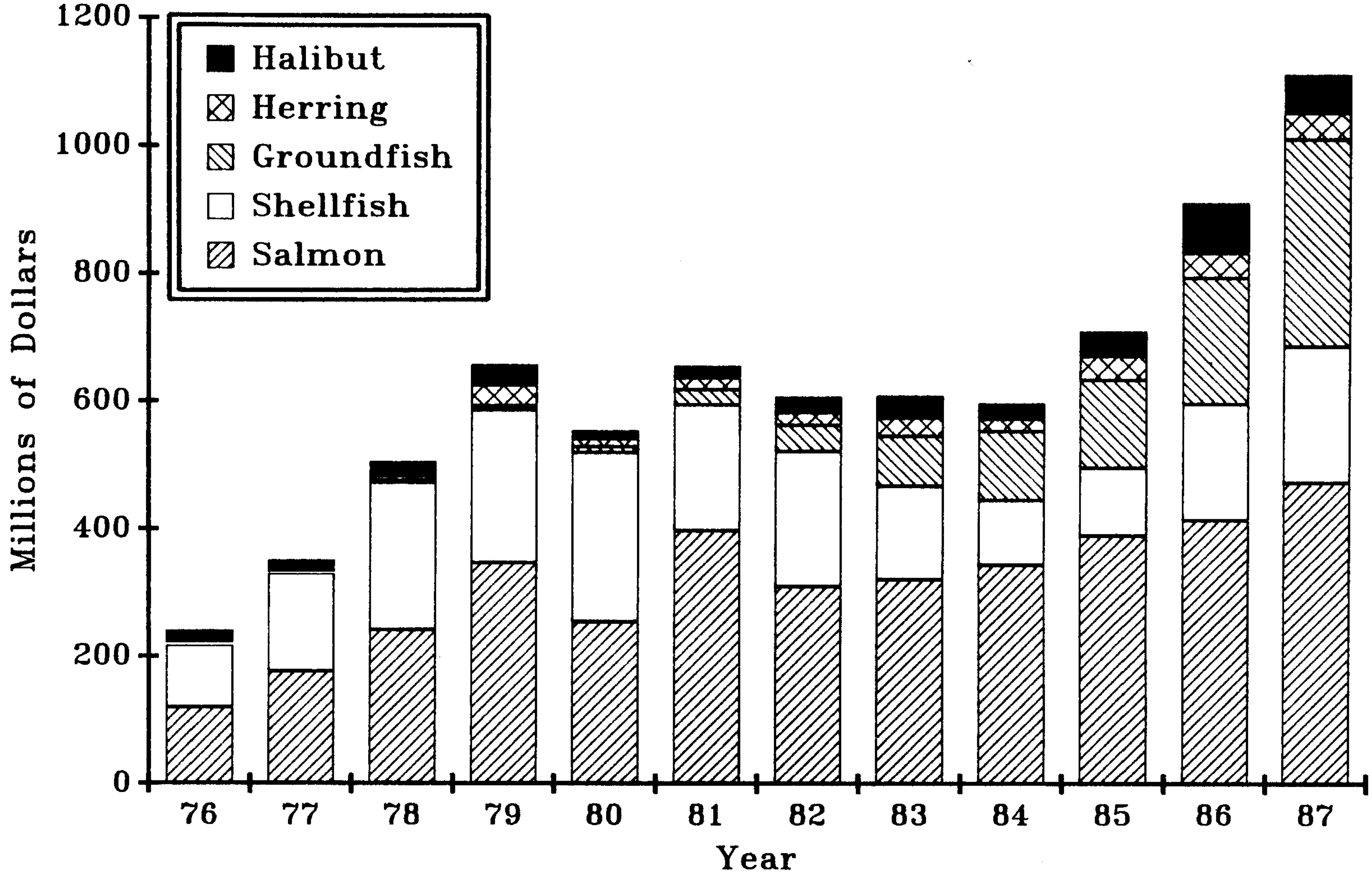

Figure 2. Exvessel value (in millions of dollars) of domestic commercial catches of major species groups caught off Alaska in 1976-87.

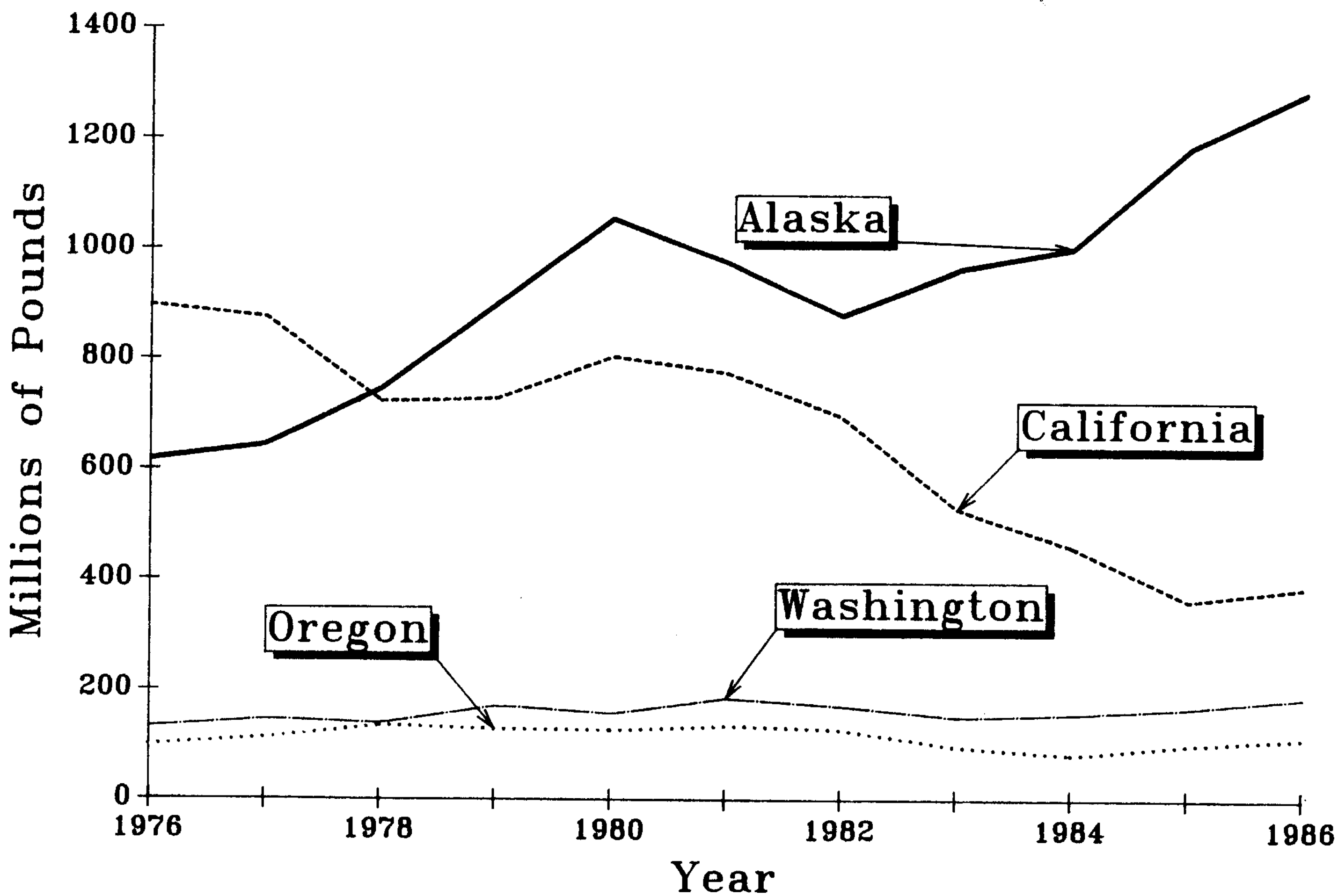

Figure 3. United States commercial fisheries landings (millions of pounds) for the Pacific Coast states for 1976-86.

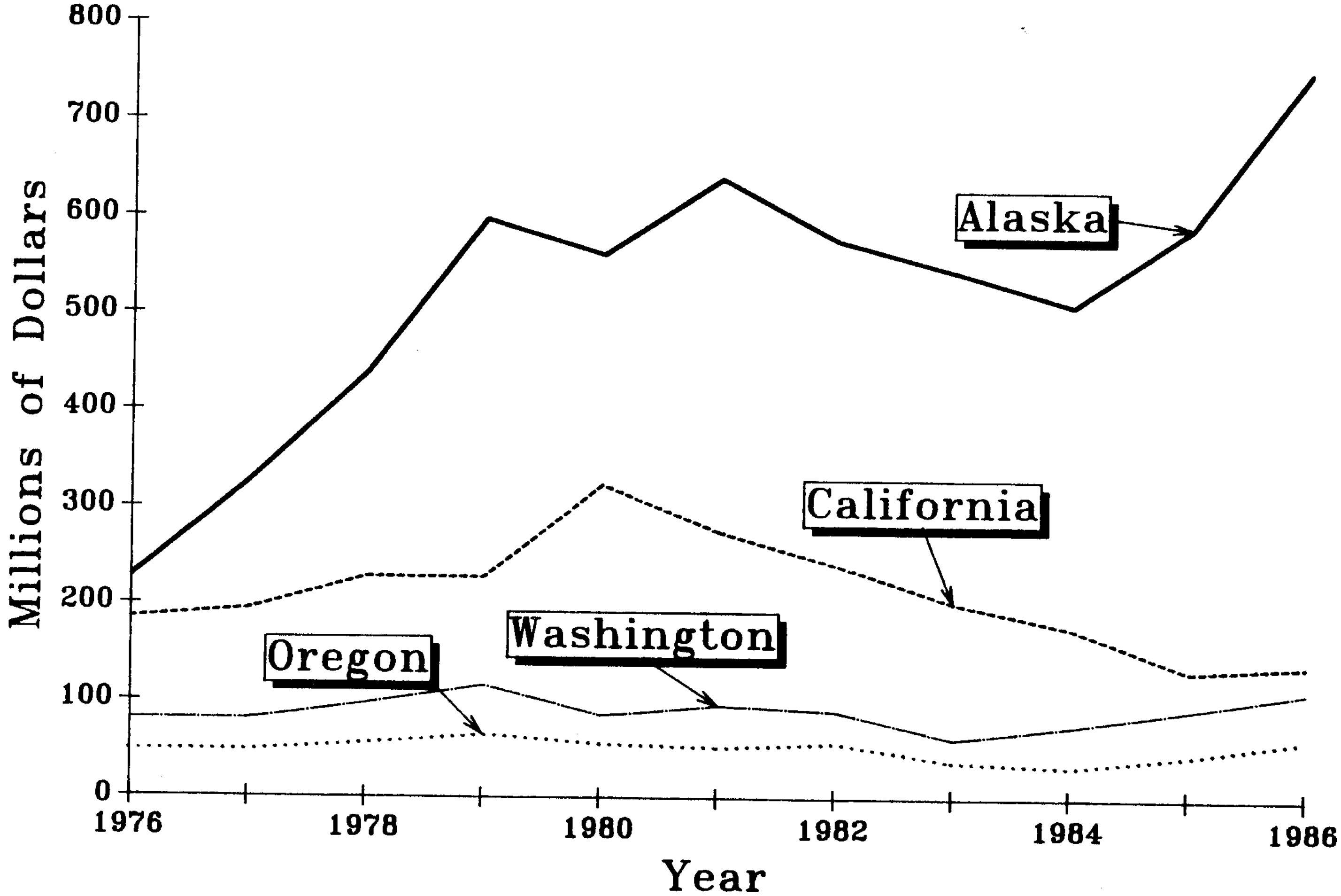

Figure 4. Exvessel value (millions of dollars) of United States commercial fisheries landings for the Pacific Coast states for 1976-86.

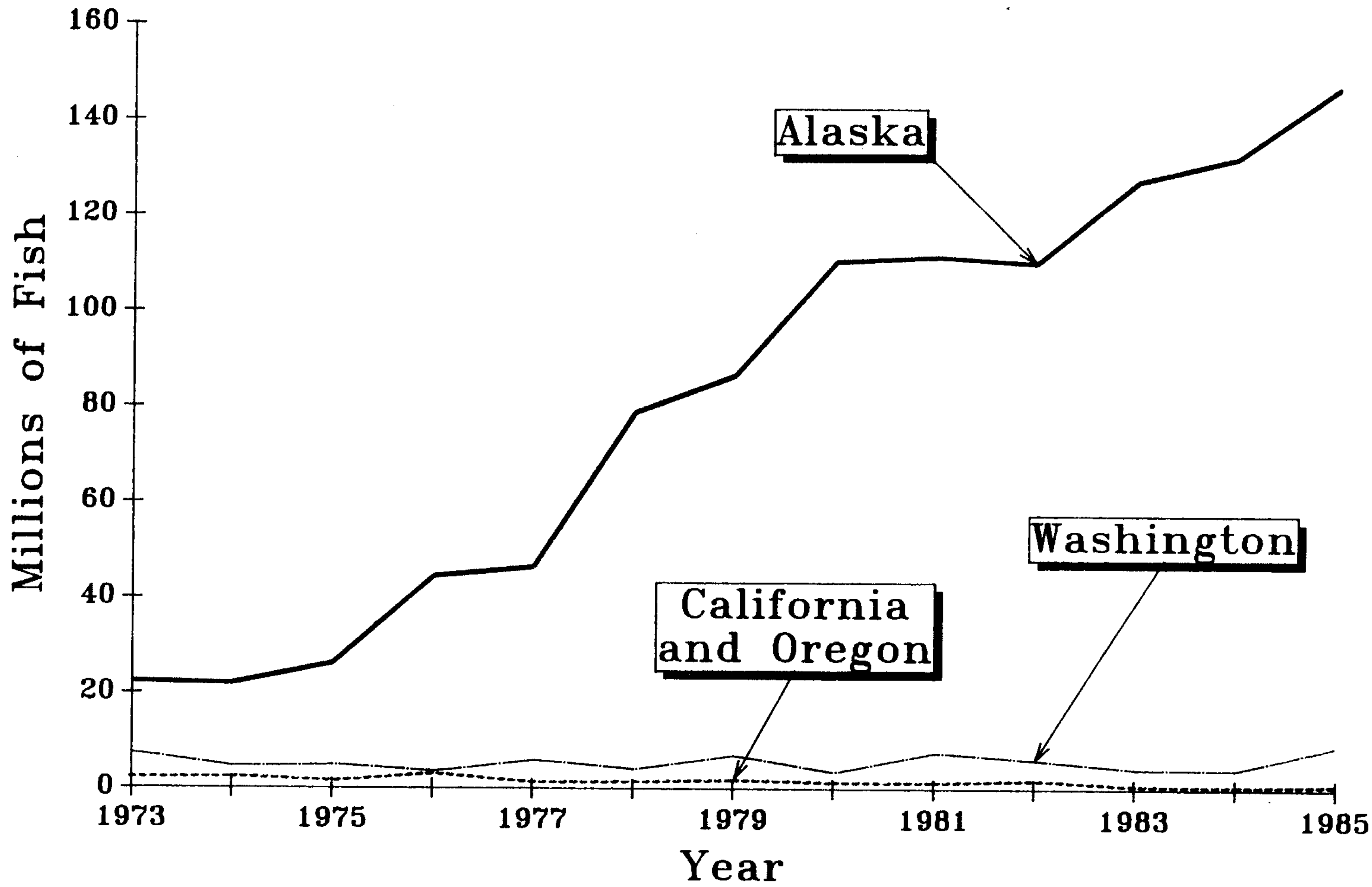

Figure 5. Commercial landings (thousands of fish) of salmon along the Pacific Coast of the United States for 1973-85.

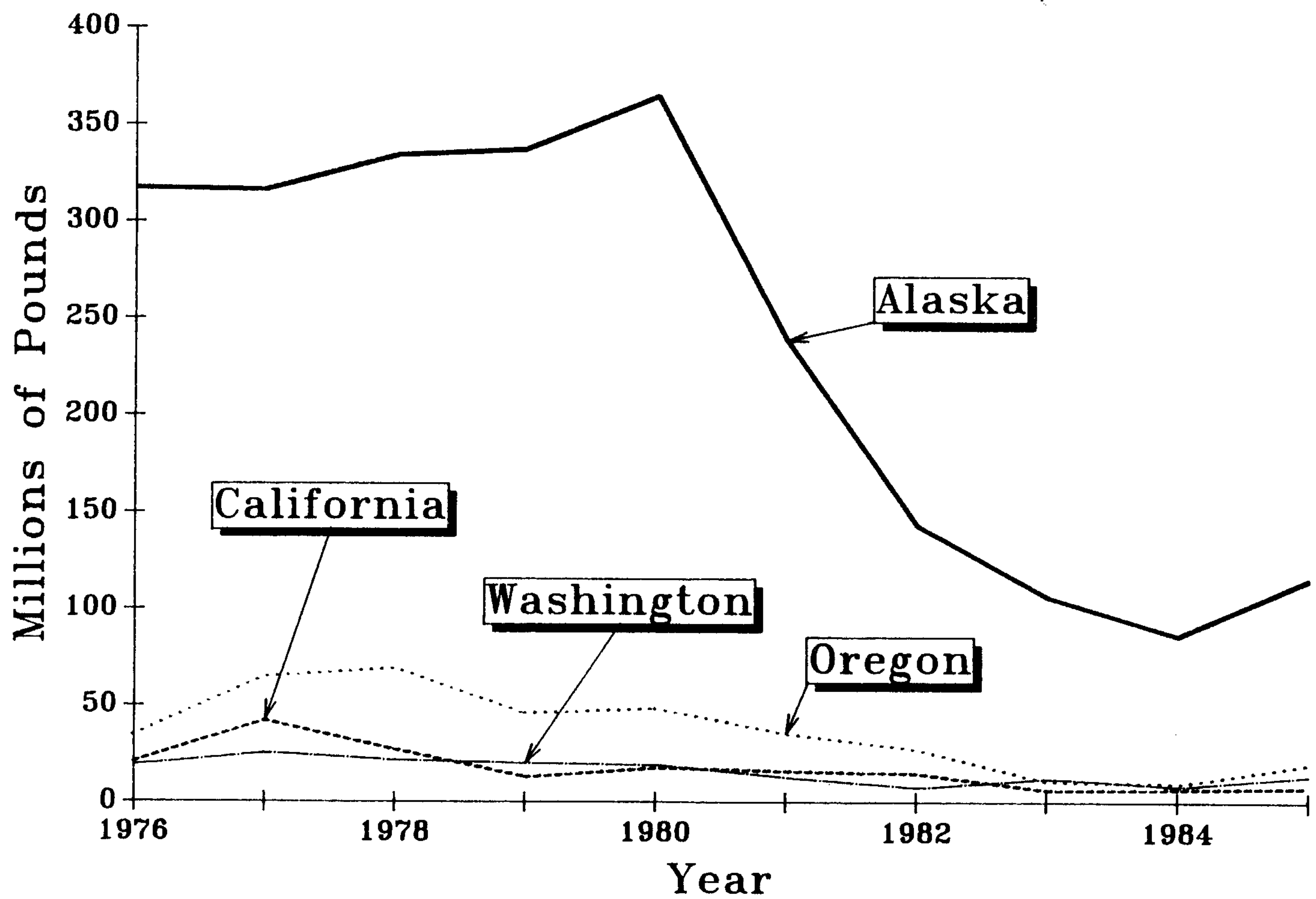

Figure 6. Shellfish landings (millions of pounds) into Pacific Coast states for 1976-85.

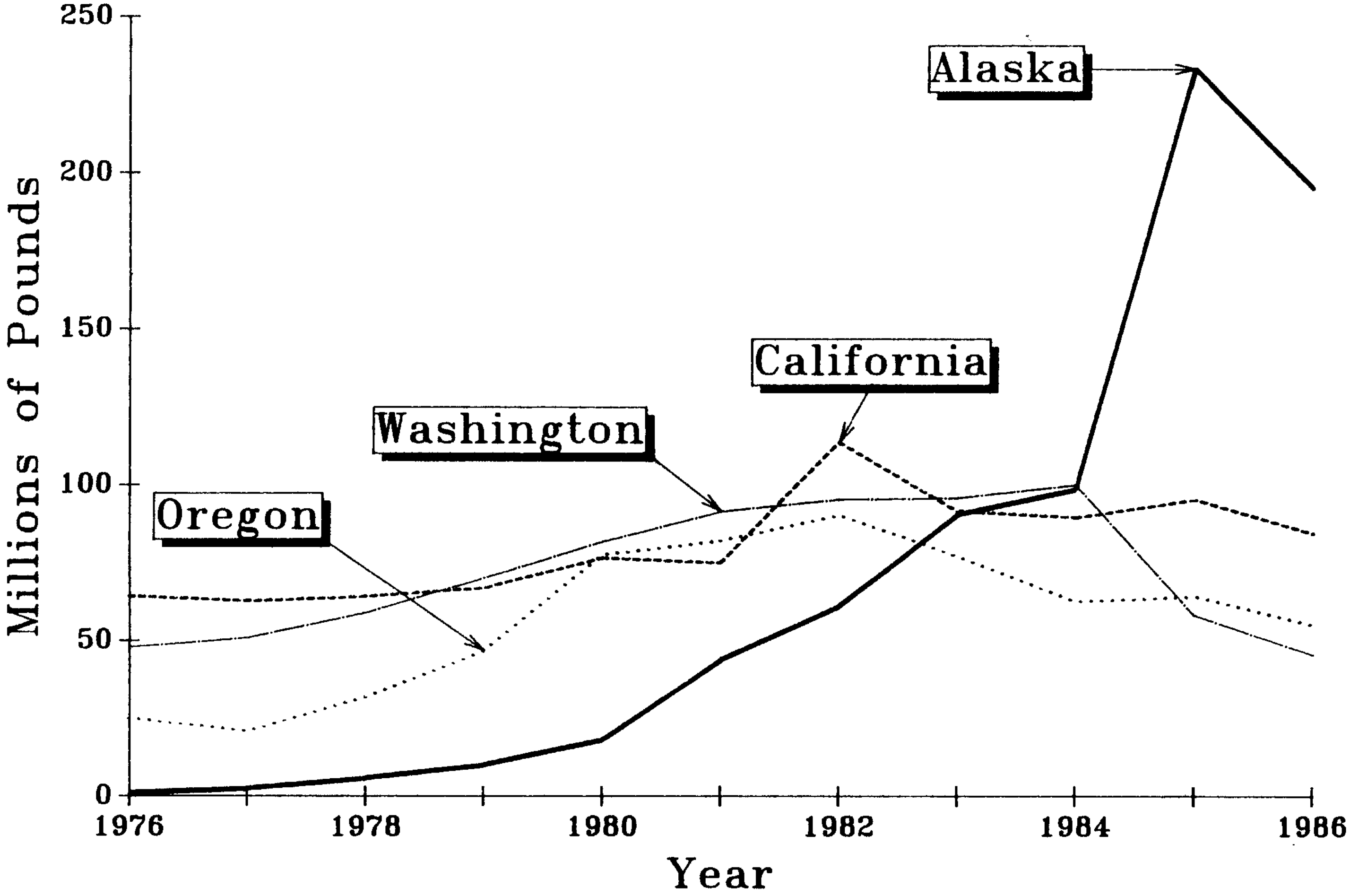

Figure 7. Pacific Coast groundfish landings (millions of pounds) by state (excluding joint venture and foreign fisheries) for 1976-86.

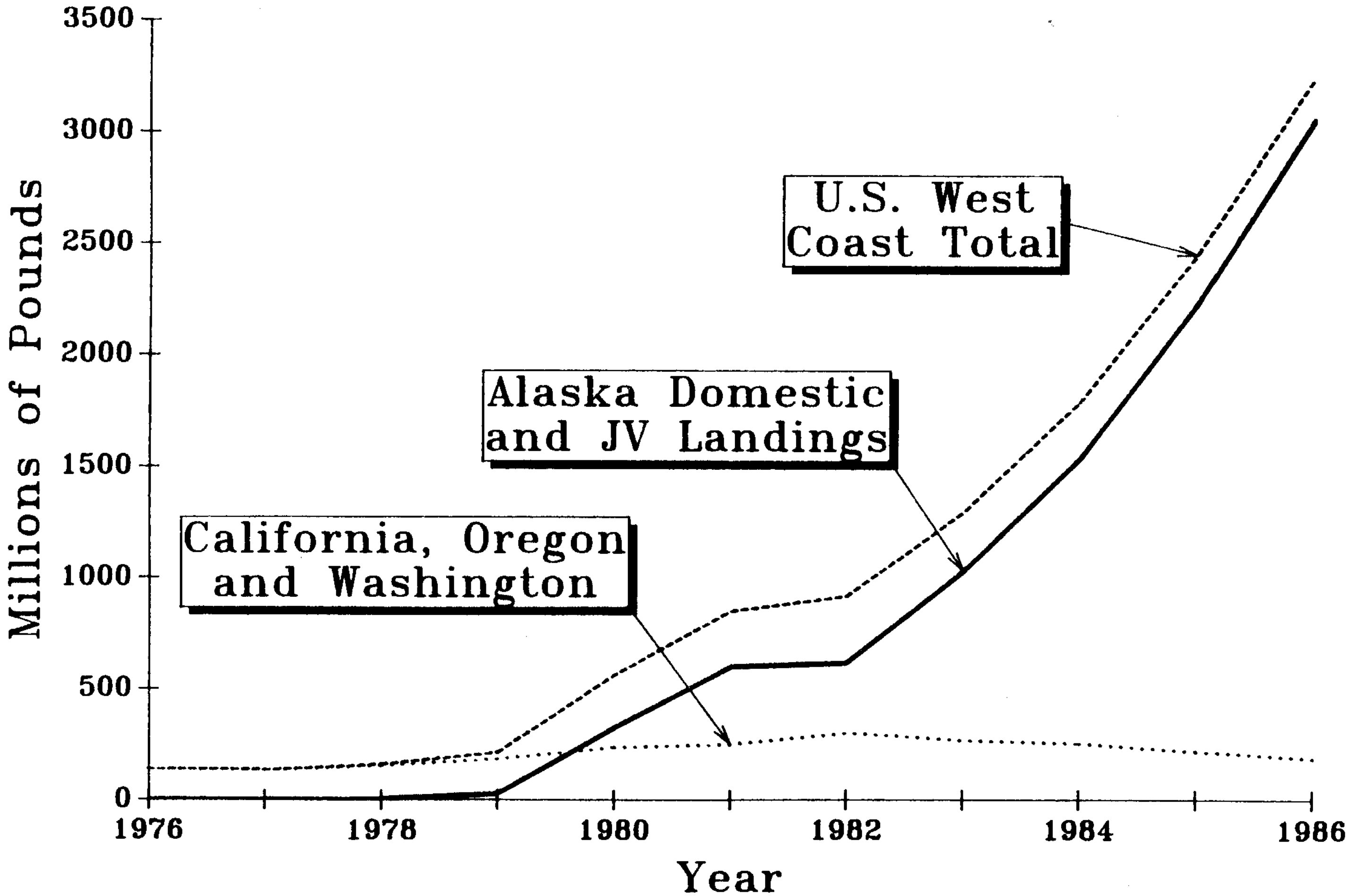

Figure 8. Pacific Coast groundfish landings (millions of pounds) including joint venture catches taken off Alaska for 1976-86.

IMPORTANCE OF COMMERCIAL FISHERIES TO ANCHORAGE

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INTRODUCTION

If Alaska were an independent nation, it would rank sixth in the world in poundage of fish produced. The ex-vessel value (gross receipts to U.S. fishermen) of fish and shellfish harvested from Alaskan waters and immediately offshore has grown dramatically from 857 million pounds worth $622 million ten years ago (1979) to approximately 5 billion pounds with a projected value of $1.5 billion by the end of this year. The wholesale value of the 1988 harvested is expected to exceed $3 billion.

While there is growing recognition of the world class position held by Alaska's commercial fisheries, the role that this industry plays in the economy of Anchorage is largely undefined. The McDowell Group (management and economic consultants) is presented conducting a formal analysis of the economic profile of the seafood industry in Alaska which is to include a South Central regional component. While the McDowell study is underway, this report can serve as an interim analysis of the importance of commercial fishing to Anchorage. Since the authors are biologists, only the direct benefits of the commercial fishing industry will be discussed. A more thorough analysis of secondary and tertiary economic values is best left to economists.

The impact of the commercial fishing industry on Anchorage will be considered within four categories:

(1) Fish Harvesting Sector

(2) Fish Processing Sector

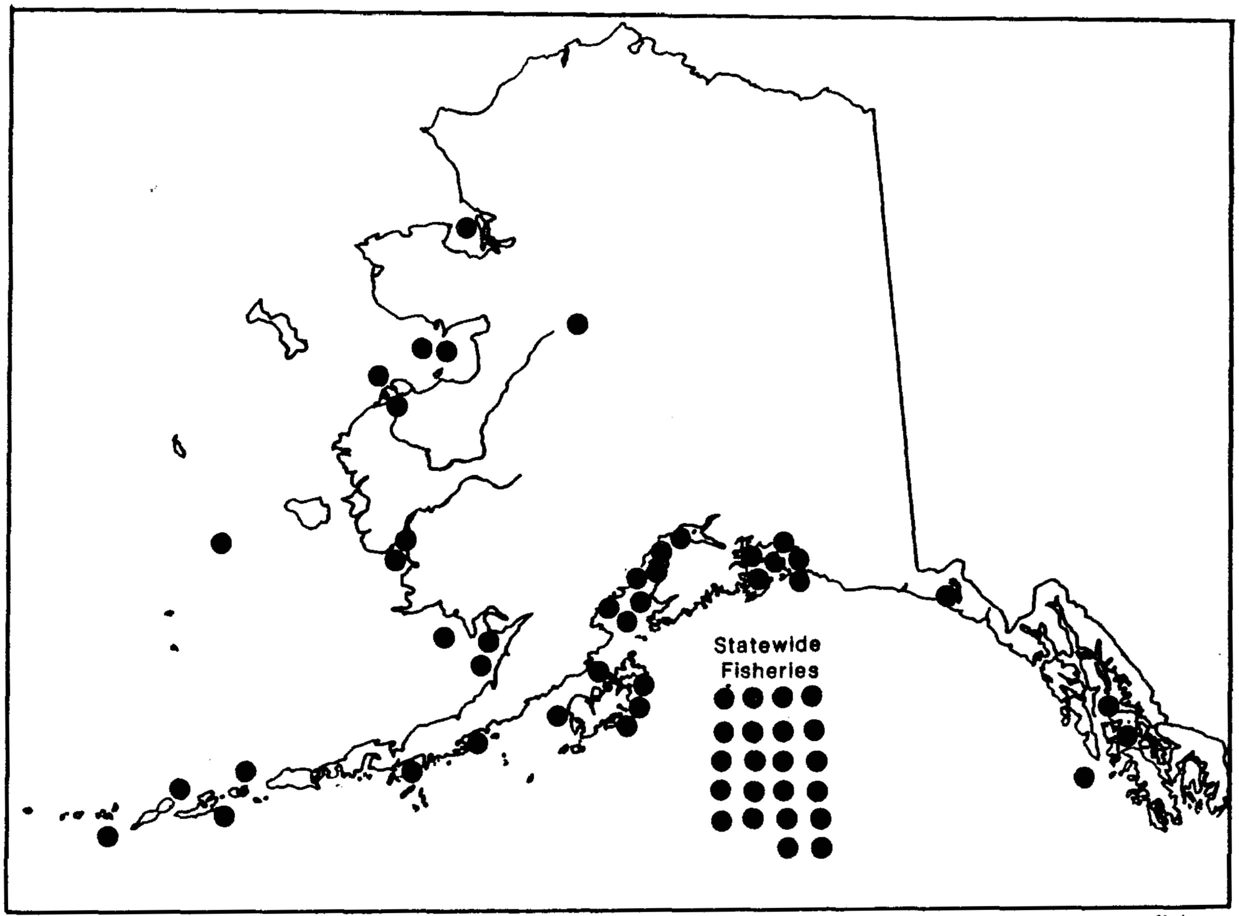
(3) Fish Transport Sector

(4) Fisheries Support and Administration Sector

FISH HARVESTING SECTOR

In 1988, over 2,500 Anchorage residents were employed as commercial fishermen. Based on projections from data provided through the Commercial

Fisheries Entry Commission, an estimated 900 commercial fishery permit holders, participating in 66 different commercial fisheries (Figure 1) scattered throughout the state, reside in the Anchorage census district (census district 13).



*Each point represents one fishery

Figure 1. Locations of fisheries in which Anchorage residents participate*.

Encompassing a diversity of fisheries from Bristol Bay salmon drift gill nets to statewide razor clams, Anchorage fishermen will be paid an estimated $43 million for their catch in 1988 (Figure 2).

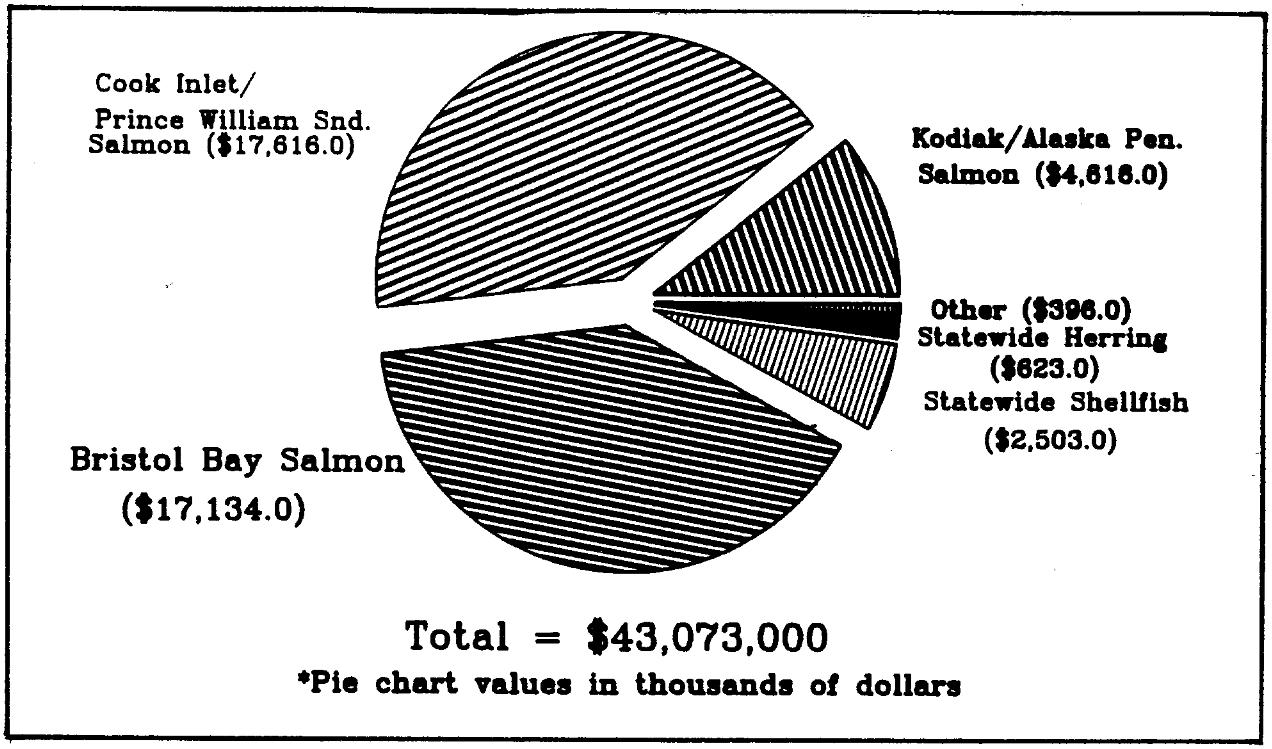


Figure 2. Source of income to Anchorage resident commercial fishermen, by region, 1988.

Based on projections from license data compiled by the Alaska Department of Revenue, an estimated 1,600 Anchorage census district residents are employed as crew members with commercial fishing operations. At 2,500, the total number of Anchorage residents who are directly involved in the commercial harvest of finfish and shellfish supports Anchorage as Alaska's largest fishing village.

FISH PROCESSING SECTOR

Five companies have operated processing facilities in Anchorage during recent years. From salmon to squid, these companies purchase millions of pounds of seafood consisting of 21 different items from virtually every area of the state. Based on 1987 data, seafood products purchased by

Anchorage companies came primarily from Prince William Sound, Bristol Bay, and Cook Inlet (Figure 3). Additionally, a signifcant portion originated in the Actic-Yukon-Kuskokwim region. These Anchorage based fish processing plants employed an estimated 950 people in 1988.

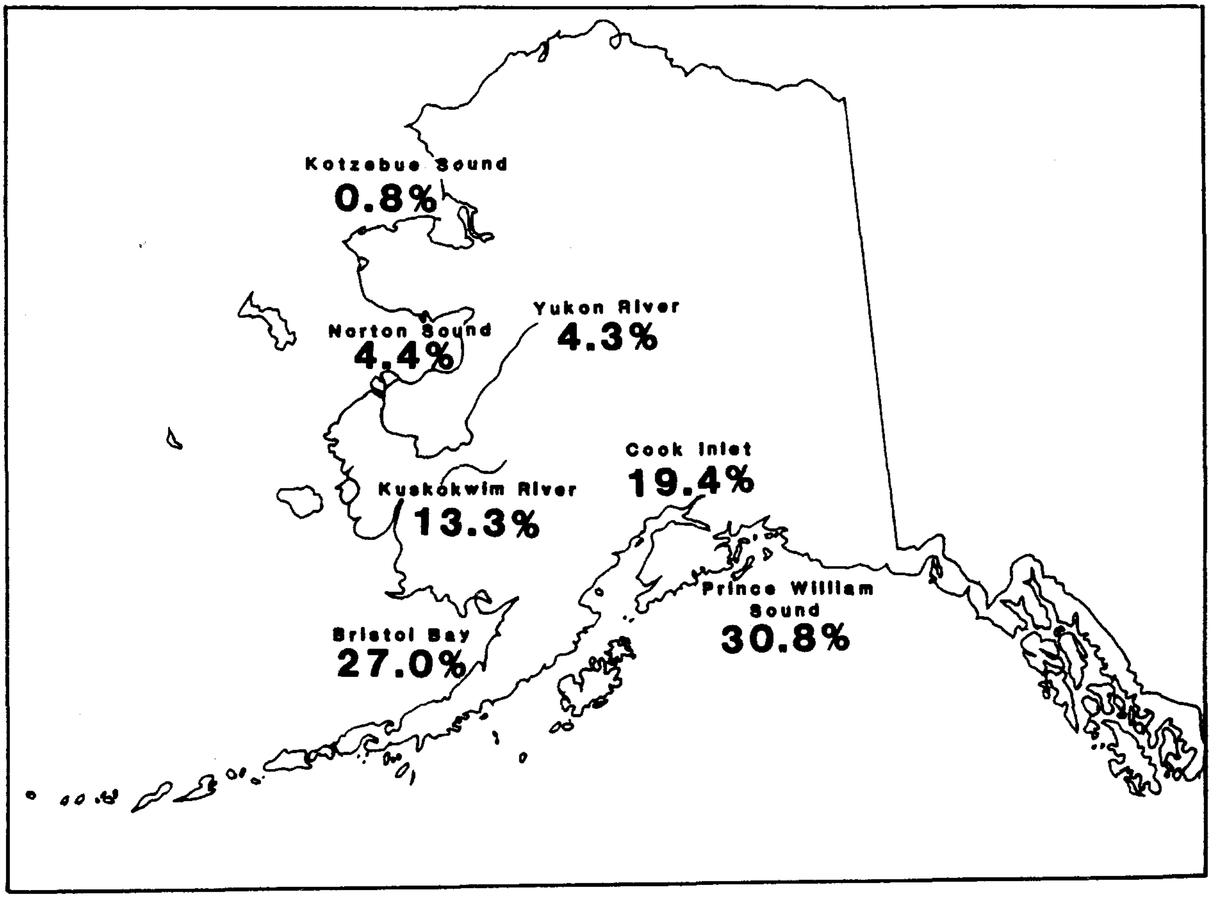


Figure 3. Regional percentages of total ex-vessel revenues paid by Anchorage processors, 1987.

Within the past three years, the amount of money paid to fishermen by Anchorage fish processing companies increased from $2 million as listed in processor reports for 1986 to more than $32.5 million projected for 1988 (Figure 4).

Wholesale values of fisheries products produced also appear to have risen sharply over the last few years (Figure 4). Based on data provided from these companies through commercial processor reports for 1986, first wholesale value of fishery products totaled $6 million that year. Based on telephone and personal interviews, the total first wholesale value of fishery products produced during 1988 will be $45 million.

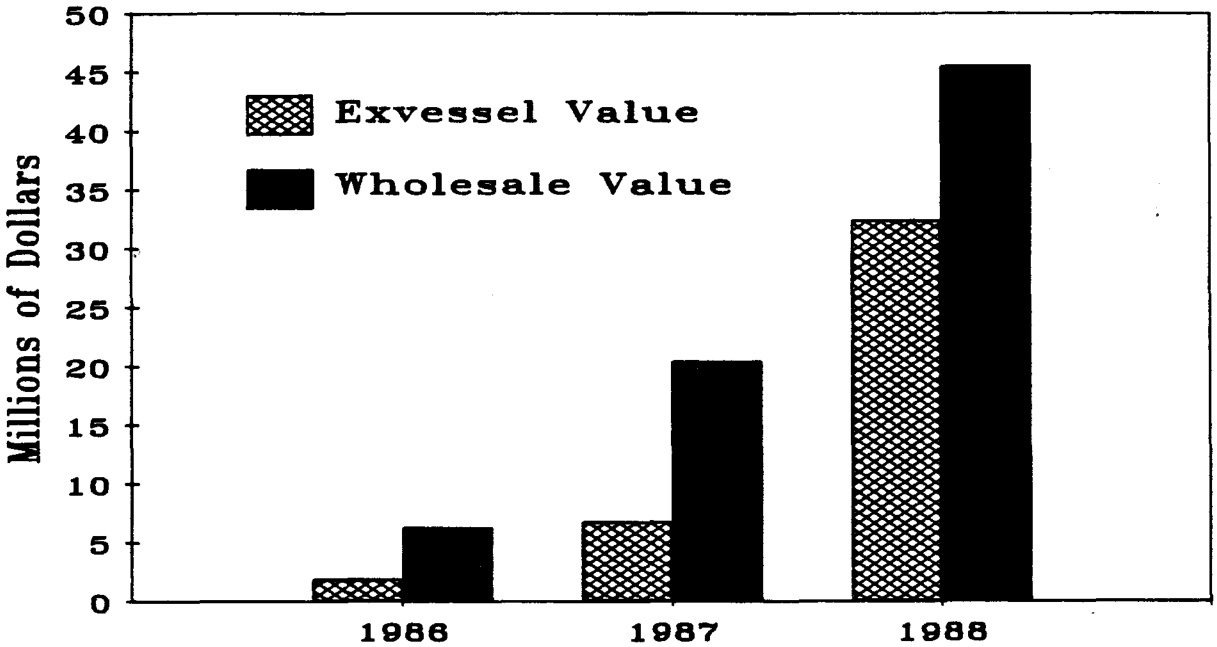


Figure 4. Ex-vessel and wholesale value of products processed by Anchorage seafood companies, 1986-1988.

Anchorage also serves as one of the primary souces of seasonal employment for seafood processors throughout Alaska. According to Alaska Department of Labor statistics, in 1987 Anchorage Job Service advertised 717 jobs in seafood processing, or 35% of the statewide total. People hired into these positions were paid an average $8.50 per hour and worked 48.5 hour work weeks.

FISH TRANSPORT SECTOR

Fish and fish product transport represents another important element of the commercial fishery industry in Anchorage. Not only are raw fish transported to Anchorage for processing from areas throughout Alaska, but fish and fish products are also transported from and through Anchorage to locations in the lower 48 states and to countries throughout the world. Revenues derived from land and air transport are expected to total $25-$30 million for 1988.

Seven ground transportation companies in Anchorage move fish into and out of the area. These firms reported employing 40 people for seafood operations. Their freight revenues for 1988 are anticipated to total $11.6 million.

Nine air carriers with facilities in Anchorage transported in excess of 70 million pounds of seafood into and out of Anchorage International Airport this year. Two of these companies shipped significant amounts of salmon, salmon roe, live crab, shrimp, and sea urchins directly to the Japanese market from Anchorage. Air transport companies reported employing 107 additional people to accommodate seafood transport. Air freight revenues generated from fish transport during 1988 are anticipated to total $16 million.

The Port of Anchorage serves as a conduit for a considerable volume of frozen fish export. An estimated 2,000 freezer vans of seafood products left Anchorage via the Port in 1988, providing nearly $500 thousand for inbound and outboard wharfage fees to the city.

FISHERIES SUPPORT AND ADMINISTRATION SECTOR

With access to modern transportation systems and services, Anchorage represents an administrative hub for various State and federal fisheries agencies, and private industry fishery groups. A conservative estimate of the employment by these groups is 156 individuals whose wages and operating budgets inject $10 million into the Anchorage economy.

As an administrative hub, Anchorage serves as host for a wide variety of fishery meetings. The North Pacific Fishery Management Council typically hosts 5 meetings a year. Attendance at these sessions usually totals between 100 and 200 people, a large number of whom come from out-of-state and several foreign countries. Each such meeting generates transportation, hotel accommodation, and meal expenses estimated to total between $50 thousand and $100 thousand. The Alaska Board of Fisheries also typically hosts multiple meetings each year. In 1988, the Board will hold a total of 33 days of meetings in Anchorage. These meetings draw hundreds of fishermen, processors, and biologists from throughout the state as well as from locations in the continental United States. Anchorage will also serve host to a projected 1,000 fisheries biologits from throughout the world at the Sepatember 1989 meeting of the American Fisheries Society.

The Anchorage area houses a variety of commercial fisheries sales and support groups including manufacturers and suppliers of fishing nets, hooks and other equipment, boat and motor sales and repair, and even distributors of paper boxes and plastic liners used to transport the harvest. The size of these companies varies from "Ed's Net Works", which is overseen by the father and employs 4 members of the family, to Alaska's largest seafood wholesaler which employs nearly 30 people. In total, this support element is estimated to employ 96 people and to generate more than $5 million.

SUMMARY

The commercial fishing industry plays a major role in the Anchorage economy. A total of approximately 3,900 people are directly associated with the harvesting, processing, transport, and support and administrative aspects of the commercial fishing industry (Figure 5). The largest component consists of 1,600 crew members, for which no estimate of crew-share income is available. The second largest component is represented by 900 Commercial Fisheries Entry Commission permit holders. We estimate that this group will be paid $3 million for their commercial fish catch in locations throughout Alaska in 1988. There are about 950 persons employed by five Anchorage based processsors who project that they will produce $45 million in seafood products at the first wholesale level during 1988. Air and ground transportation services employ a reported 150 people for fisheries transportation needs. Air and ground freight revenues associated with the movement of fish and fishery products into and out of Anchorage are estimated to total $28 million. Fishery support services employ nearly 100 people and anticipate revenues in excess of $3 million. Approximately 150 government and fishery association employees reside in Anchorage and have annual wages and operating budgets which potentially inject 10 million into the Anchorage economy.

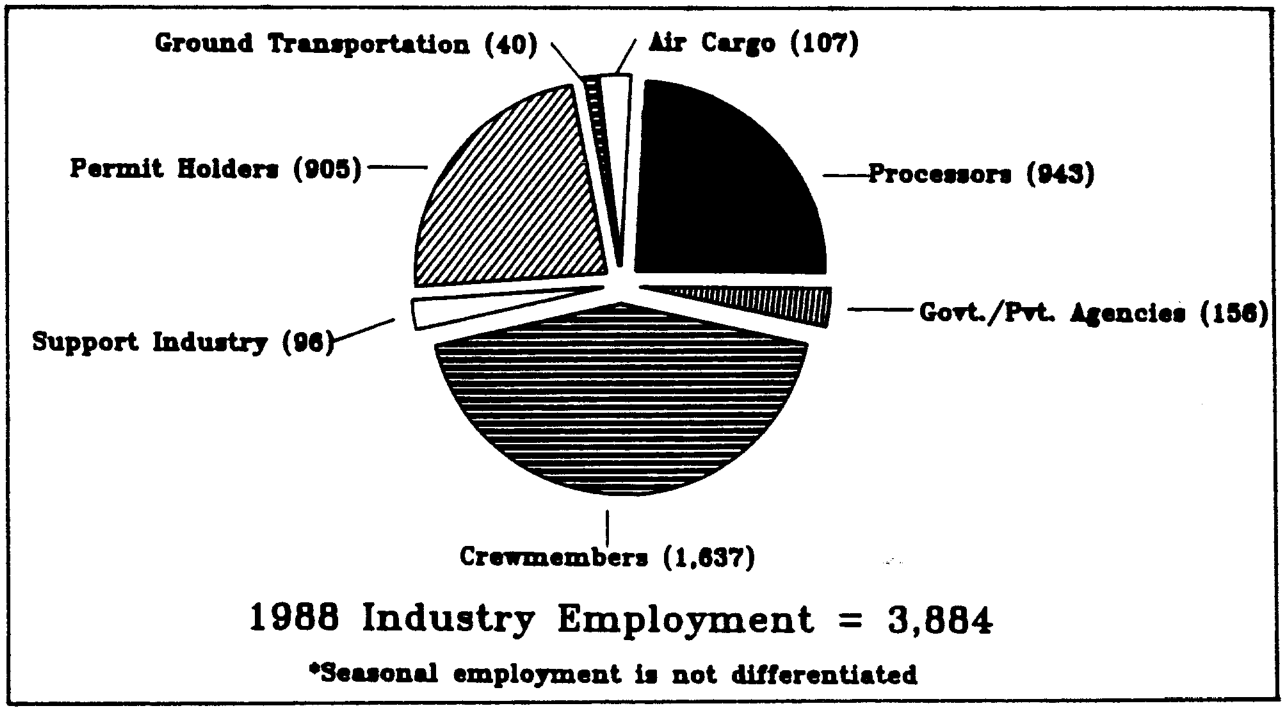


Figure 5. Estimated employment of Anchorage residents in the commercial fisheries industry, 1988*.

Additional revenues are generated from fisheries meetings which draw literally thousands of people to Anchorage from locations throughout the state and the world. There is no question that the commercial fisheries industry is of major importance to Anchorage.

KODIAK RED KING CRAB *(PARALITHODES CAMTSCHATICA)* HARVEST HISTORY AND THE IMPLICATIONS OF SIZE, SEX, AND SEASON MANAGEMENT

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ABSTRACT

The historical harvest of red king crab (Paralithodes camtschatica) stocks is assessed in light of survey data during the 1973 to 1988 period. The closure of the directed harvest from 1983 to present, coupled with a continued survey has provided an opportunity to assess population changes without commercial fishing. These data suggest that crab may survive in substantial numbers for several years after obtaining legal size. A size, sex, and season based fishery, without any regulation of exploitation rates of legal males, would have resulted in very high sex ratios during periods of low recruitment, and most probably, a very high handling rate of non-legal animals, given recent price trends. This strategy would also result in comparably low removal rates of sexually mature males during peak population years, because of the high number that were sub-legal in size. This type of fishery management policy results in the highest exploitation rates when stocks are lowest and the lowest exploitation rates, when stocks are highest. This trend is exacerbated by the price increase response to decreased volumes when stocks and harvest decline. As the Kodiak red king crab population, has had the most precise survey conducted over the longest time series of any of the Alaskan red king crab populations, this population may be a good indicator of the risk associated with other shellfish populations that are not surveyed or surveys with large errors. King crab populations with highly variable recruitment appear to be improperly managed by use of a 3-S strategy, in the sense that having a high risk of recruitment overfishing is improper management. Excessive legal male removals could not be detected by use of commercial fishing statistics alone.

INTRODUCTION

Kodiak red king crab (*Paralithodes camtschatica)* populations have been closed to commercial fishing since the end of the 1982 fishery because of low abundance and no apparent recruitment of commercial significance. The fishery, prior to this closure, was regulated by various policies. These included a size, sex, and season (3-S) policy, with little or no regulation of the exploitation rate of legal males, a constant exploitation rate policy, on legal males only, and a variable exploitation rate, using lower rates when stocks were low and higher rates when stocks were abundant.In all cases female harvests have been prohibited and the size limit was believed to provide for a conservative harvest rate on reproductive stock, regardless of the exploitation rate on the legal sized animals. The stocks have been monitored annually by use of systematic pot surveys during the years 1972 to 1986 inclusive. The 1987 and 1988 surveys were conducted by use of trawl gear. I review these data and based on this review suggest several hypotheses which are to be explored by further analysis of this information in addition to data from other sources. Specifically, the practice of regulating shellfish fisheries by means of size, sex and season alone is questioned.

METHODS

The continental shelf along Kodiak Island has been surveyed for red king crab relative abundances by use of standardized crab pot surveys, in addition to recent trawl surveys. The methods and specific location of the sampling sites used in these surveys are described by Peterson et. al. (1986), Blau (1986) and Donaldson (1987).

The carapace length (CL) frequencies obtained from these surveys, coupled with the effort, described in this report as pot lifts, are the basis for the data plots presented. The length data were pooled into 2-mm increments for developing the three dimensional plots presented in this report. The effort from the 1987 and 1988 trawl surveys, was equated to the pot surveys by assuming the trawl effort was equivalent to 448 pot pulls. This approximation was based on the number of crab per unit effort equated by repetitive surveys in the Alitak area of the southwest district in 1985. Because of the low stock abundance, survey precision error will most likely far outweigh any error made by this assumption. This will be refined in future reporting.

Biomass was estimated for each size class of crab by using the formula from Blau (1988):

$$W = 4.45174 \times 10^{-4} (L \wedge {}^{3.11937})$$

Where: W = the weight of an individual crab in grams

and L = the length of an individual crab in millimeters

The ex-vessel average price per pound used to calculate value was obtained for the years 1972 through 1982 from Alaska Department of Fish and Game fish ticket averages. The 1983 price per pound was the average fish ticket value reported from the Adak red king crab fishery for that year, while the 1984 through 1988 ex-vessel average prices were from the Bristol Bay red king crab fishery reports. The prices were converted into standardized 1967 dollars using the U.S. Bureau of Labor statistics reflecting consumer prices.

RESULTS

Figures 1 through 4 depict four different views of a three dimensional plot of Kodiak red king crab 2-mm length classifications, for the 16 years of the survey. Each graph contains the data for the relative indices of male crab plotted by numbers/pot, biomass/pot, and ex-vessel value/pot in addition to female numbers/pot. For 1987 and 1988 when trawls were used, a trawl haul was equated to a pot lift as described previously.

The current legal male minimum size limit (in width) equates to approximately 148-mm (CL). The plots of the male data contain in excess of 400,000 male crab length measurements, while the female data contain in excess of 300,000 measurements. Several trends are apparent. First, recruitment of age classes to the survey gear in appreciable numbers occurred only during 1972, 1976, 1977 and 1980. From other studies this size class of animals can be identified as having settled as larvae during the summers of 1967, 1971, 1972 and 1975, respectively. This assumes that the growth rates identified in these studies remain consistent and are applicable for the years described. Most striking is the failure of recruitment to the survey gear in all 12 other years of the survey. The age classes that subsequently grew to legal size (approximately 148-mm CL) during the survey period, can be tracked by observing the mode of the length frequency data, with a relatively high degree of precision. Although numbers decreased, biomass remained constant or increased up until the cohort of crab recruited to legal size. Variations in biomass are easily masked by scale error variations in the survey. Consequently variations in natural mortality rates of both female and male crab appear to also be within the scale error[1] of the survey.

The biomass in the early years tended to accumulate at post legal size, probably reflecting the multiple age classes present in the fishery and lower exploitation rates of the legal crab. The dramatic decline in biomass, numbers, and to a lesser degree, value, occurred between 1981 and 1982. This was reflected in very high commercial crab landings. These commercial catches, combined with negligible recruitment, were probably the cause of this decline. Although females declined rapidly during this period as well, the differential mortality rate between female and male crab from 1981 and 1982 was equivalent to an instantaneous mortality rate in excess of .7 for each year.

The cohort of crab that first appeared in the survey gear during 1980 was found only in the southwest portion of the continental shelf around Kodiak. This population did not recruit to legal size until 1983, the first year of

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[1]Scale error is the variability in the vertical axis of the graphs. This may occur because of either bias or precision errors associated with the survey effort. These errors are most obvious when a cohort of crab shows a positive increase in relative abundance in a subsequent year. Although for small crab, this may reflect recruitment to the survey gear, the errors are not easily explained for larger crab sizes, for example the differences between 1972 and the 1973 surveys.

the commercial fishing closure around Kodiak. Because of the relatively small numbers, and no subsequent recruitment, this population has never been exploited by commercial fishing gear. Although its absolute abundance is subject to comparably high precision error, it has been sustained in significant numbers up through 1988, although accelerated mortality occurred between 1985 and 1986 on the male animals. This apparently did not occur on the females. Over 70% of the male animals in this population have been above the minimum legal size since 1985.

The female data have followed the same general pattern as that of male animals with some exceptions. Notice that even when the female age groups are three years apart, they become quickly indistinguishable from the older cohorts after they reach an estimated age 7. Identification of female age based on size is quite difficult. Also of interest is the rapid decrease of female animals from 1981 to 1983. This population has not been subjected to a commercial fishery. This rapid decrease did not occur on the female population that first recruited to the gear in 1980 (probable 1975 brood year) at approximately the same age. The error associated with the estimate of this cohort in recent years however, makes this inference somewhat speculative.

The value of crab between years somewhat dampens the variation in biomass that has occurred. This is an apparent response to volume changes although other economic factors such as the international exchange rate may have significant impacts on value. The value of the animals depicted does not account for probable differences in price between small and large animals.

DISCUSSION

The examination of the historical trend of the Kodiak red king crab population and values suggests certain conclusions can be made as to the probable cause of the decline of these commercial crab stocks. It is obvious that the failure of young animals to recruit to legal commercial size is the reason the fishable crab population has declined. No major recruitment has occurred since the 1972 brood year with no measurable recruitment since the 1975 brood year[2]. An examination of the female stocks in 1972, 1972 and 1975, as compared to the other survey years, does not suggest an obvious relationship between sexually mature fecund females and recruitment success or recruitment failure. If the commercial fishery were to have had an adverse impact on the female stocks, it would probably be limited to the 1982 and 1983 period. The relative change which did occur during this period of time is comparably small to that which has occurred during the history of the survey because of changing recruitment. This changing recruitment was apparently not related to female abundance. This suggests that commercial fishing activities have had, at least in the past, minor effects on the recruitment of legal animals to the fishery.

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[2]This assumes the crab which recruited to the survey gear in 1977 and 1980 are correctly aged.

This does not suggest that the regulation of commercial fishing activity was without benefit. The very large decreases in the population of legal males which occurred in 1981 and 1982 are most probably explained as an impact of commercial fishing. It is of concern that the female population also underwent a marked decline when this fishery occurred. A similar decline in females did not occur in 1984 and 1985. The crab present during these years should have been a similar age as those in the 1981 and 1982 population. Potential mechanisms for fishing induced mortality on females include sorting and handling impacts, ghost fishing of lost pots, and very few males present at the time of molting (potentially increasing the probability of predation). With the commercial fishing closure which occurred in 1982, the sex ratios of the population which has sustained the current reproductive population have remained relatively constant. The female population continues to be dominated by very large and apparently old individuals. If the stock is to recover sometime in the future, these low female populations appear to be the only source of reproductive potential to support this recovery.

The impact of a total 3-S management system on sex ratios, which assumed 90% exploitation rate on legal male animals is depicted in figure 5. This figure also provides liberal and conservative assumptions on the minimum size to sexual maturity of male animals. One hundred and two mm (CL) approximates the female size at maturity and is used as the liberal interpretation. The 137 mm (CL) length is the approximate size of male reproductive entry as obtained from diving observations of naturally observed mating pairs, collected during the late 1960's and early 1970's (Unpublished data from ADF&G, Kodiak). The actual sex ratios which occurred as a result of our past management practices are included for comparison. The data represent the resultant sex ratio which would have occurred historically if a 3-S season would have been initiated during that particular year. Regardless of the assumption, sex ratios would have been unacceptably high (in excess of 5 females/male) during the recent major decline in stocks. Moreover, the ratios would have been highest, when the abundance of reproductive animals was at or near its lowest point. Clearly, this would not be in line with the general management practices of other commercial fisheries.

Figure 6 illustrates the proportion of the exploitable biomass of red king crab males which is above the current legal size limit of 7 inches in carapace width (approximately 148 mm CL). This graph also depicts the fraction of the biomass available in the sublegal portions of the stock which are sexually mature under the two different interpretations of minimum size to sexual maturity described previously. Clearly, as biomass decreases to very low levels (because of recruitment failure, natural mortality, and removal by commercial fisheries), the proportion of the biomass available for harvest becomes very large.

The examination of biomass variations in a cohort from age 7 to age 10 (Figures 1-4) suggest that mortality rates are for the most part, offset by growth. Variations in this trend, and in natural mortality rates between years are masked by survey scale error. In practical terms, this suggests much leeway can be given in harvesting crab over this range of sizes and age. Variations in price per pound as a function of size and stability in landing over years are some of the considerations that should be addressed when revising our current harvest policy. Female harvests should not be precluded if recruitment is assured as they apparently have similar natural mortality rates as males, with little to be gained by forgoing any harvest. Roe bearing female crab may be highly marketable in the orient (personal communication, Robert Otto).

Finally, the apparent increased rate of mortality for age 10 and above male crab without being subject to a commercial fishery suggests that higher exploitation rates on older animals may be economically beneficial with minimal conservation concerns if recruitment is forthcoming. Without assured recruitment, commercially harvesting these stocks would most certainly result in unacceptable impacts on future recruitment. Despite apparently higher mortality rates, significant populations have sustained to an estimated age 13.

Unfortunately, not all crab stocks are surveyed, or are surveyed with a great deal of imprecision. These stocks are usually managed by 3-S policies (size, sex, and season). Because of the large impact of the marine environment on the recruitment process, the effects of overfishing would probably not be detected by monitoring commercial catch rates alone. The assumption that a 3-S policy is inherrently conservative needs to be re-examined.

CONCLUSIONS

1. Red King Crab populations in the Kodiak area are at record low levels. These low levels can primarily be attributed to many years of consecutive recruitment failure. Commercial fishing has had a minor role in the overall decline.

2. A single cohort exploited at modest rates, is capable of supporting a commercial fishery for many years, with little impact on long term yield. Average weights of crab will vary significantly over time, however, and may be a major economic consideration in determining the minimum size limit for the species.

3. Without any restriction on the exploitation rate of legal male crab, the commercial fishery is projected to have major impacts on sex ratios and consequently potential impacts on reproduction. This would tend to occur after a consecutive series of years of poor recruitment and on populations of low abundance. The exploitation rates would be driven by the value of the crab which would also accentuate the problem by causing a very high effort on the small numbers of remaining animals during periods of scarcity. Pure size, sex and season management on stocks of crab with highly variable recruitment could lead to recruitment overfishing if the data from the Kodiak red crab fishery is generally reflective of other crab stocks.

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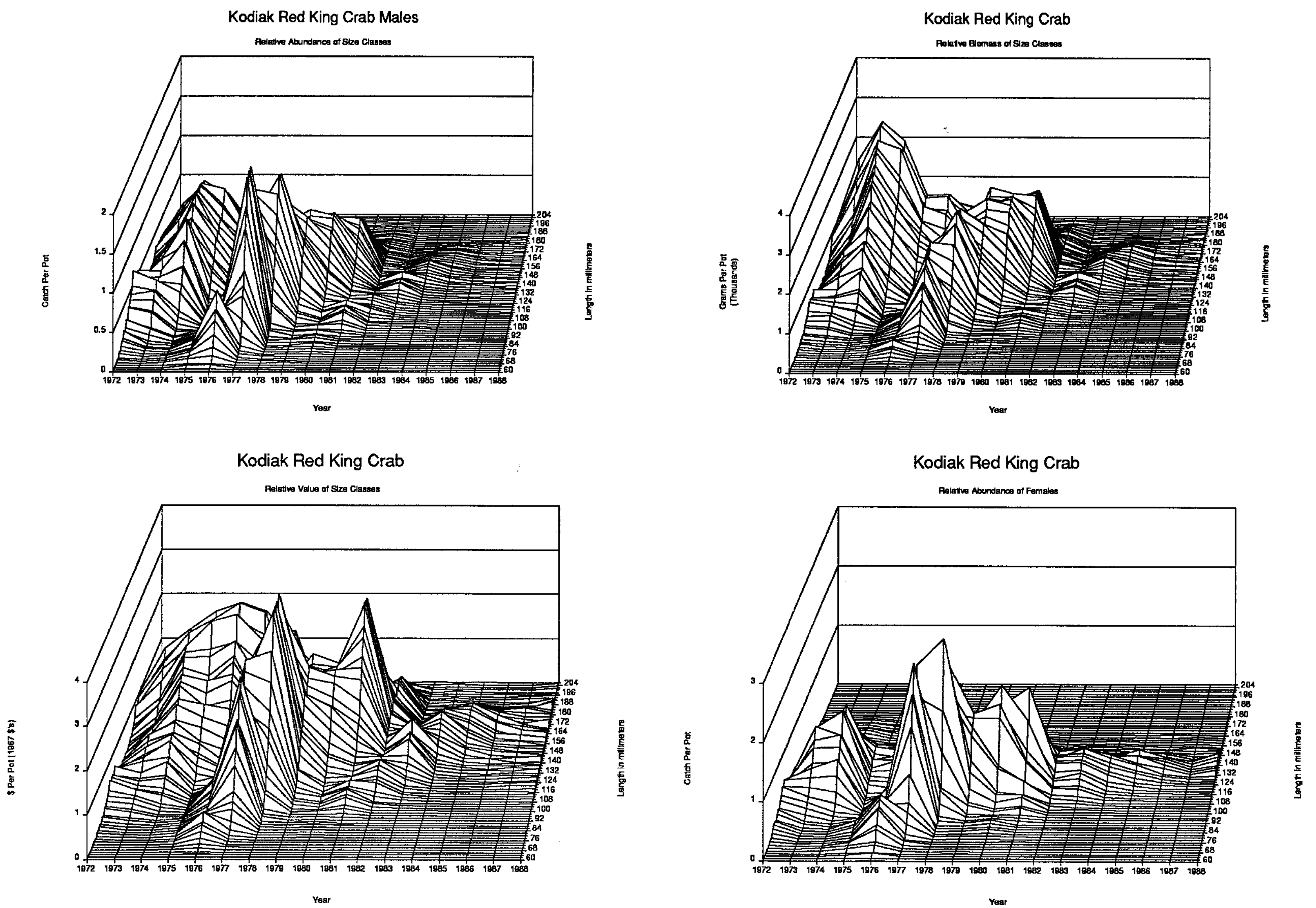

Figure 1. Length frequency data of Kodiak Red King Crab Males as numbers per pot (Upper left), biomass per pot (Upper right), nominal dollars per pot (Lower left). Females as numbers per pot are in the lower right graph. This view shows the early history of the survey in the background of the graphs.

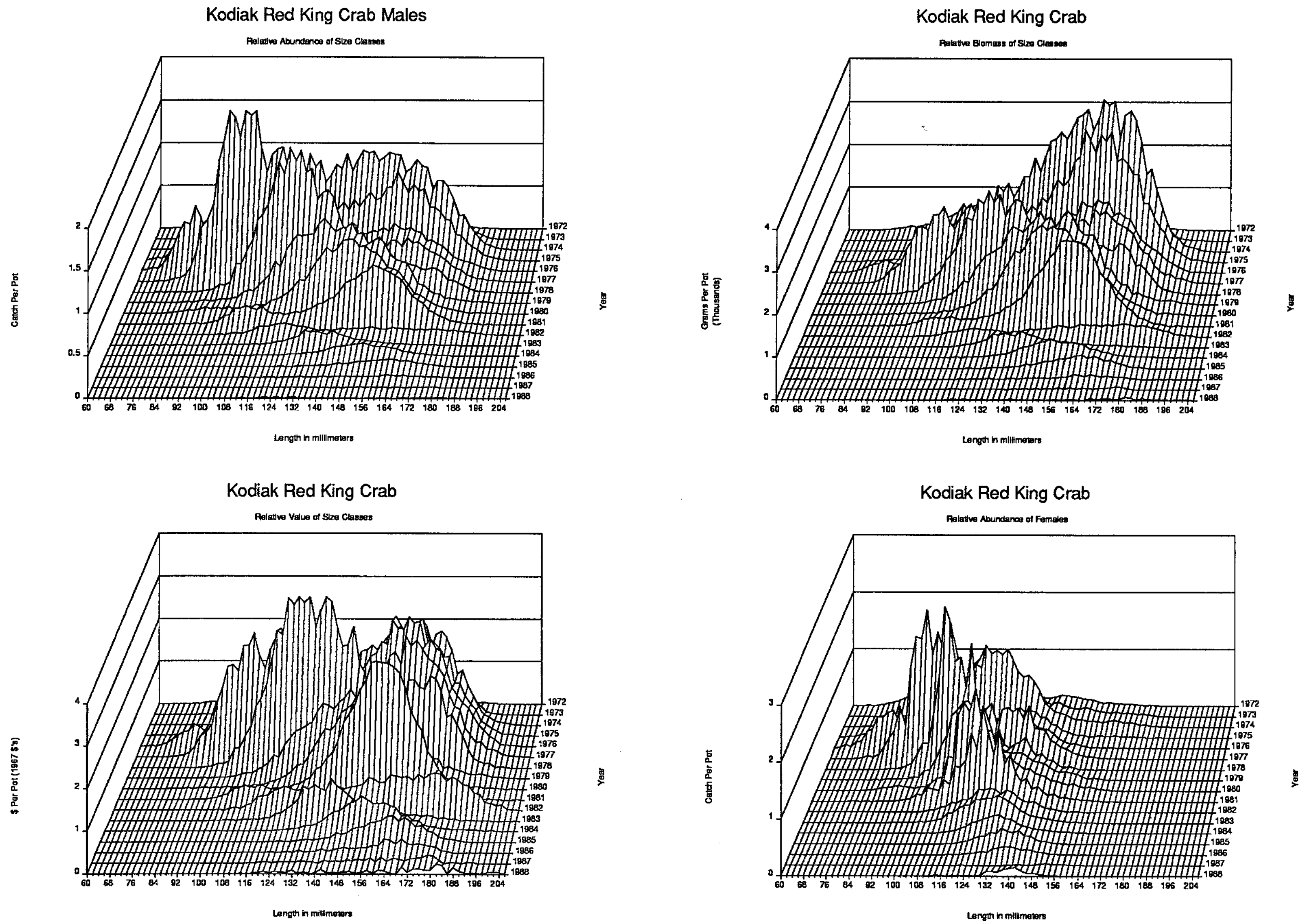

Figure 2. Length frequency data of Kodiak Red King Crab Males as numbers per pot (Upper left), biomass per pot (Upper right), nominal dollars per pot (Lower left). Females as numbers per pot are in the lower right graph. This view shows the early history of the survey in the foreground.

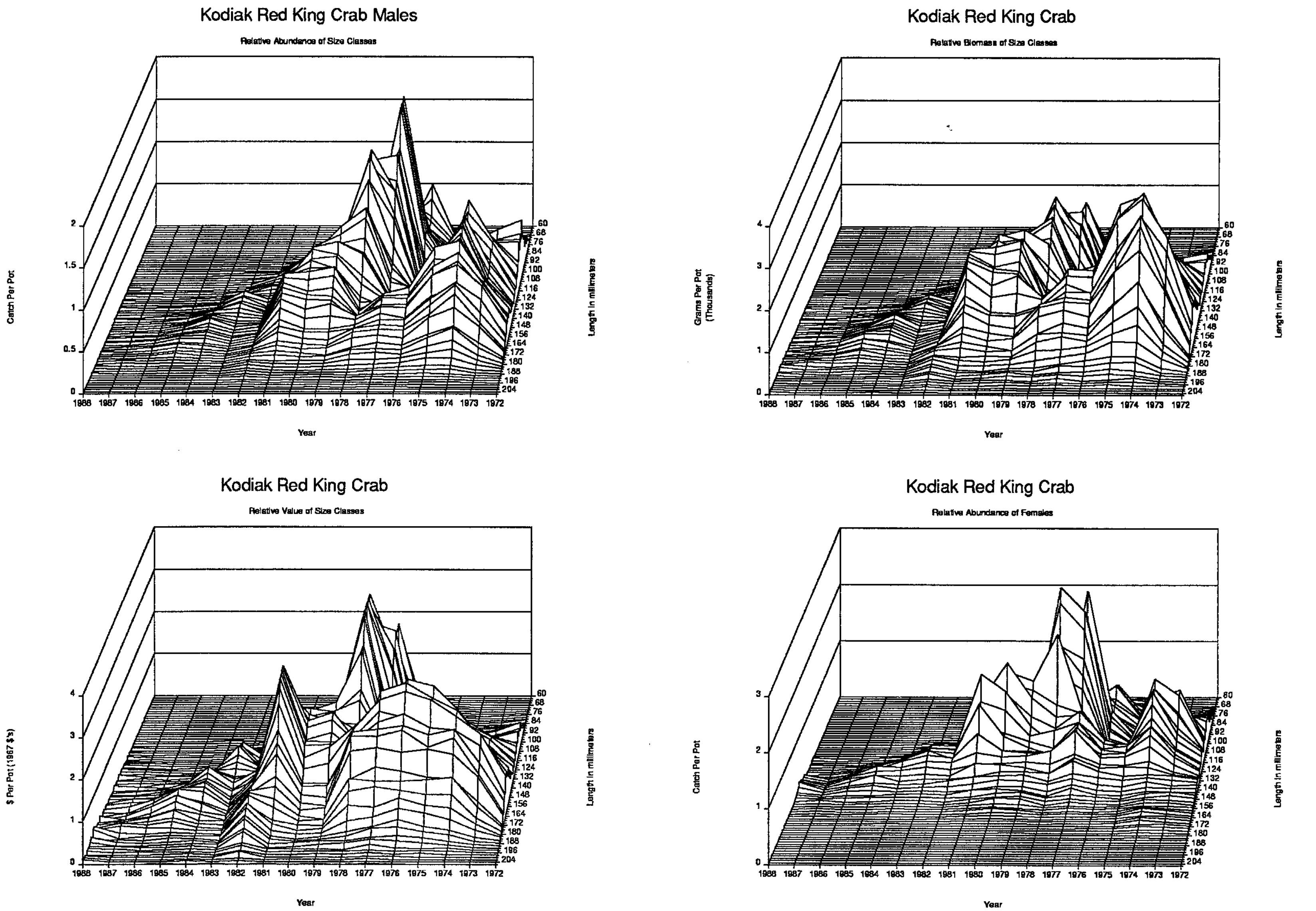

Figure 3. Length frequency data of Kodiak Red King Crab Males as numbers per pot (Upper left), biomass per pot (Upper right), nominal dollars per pot (Lower left). Females as numbers per pot are in the lower right graph. This view shows the early history of the survey to the right of the graphs.

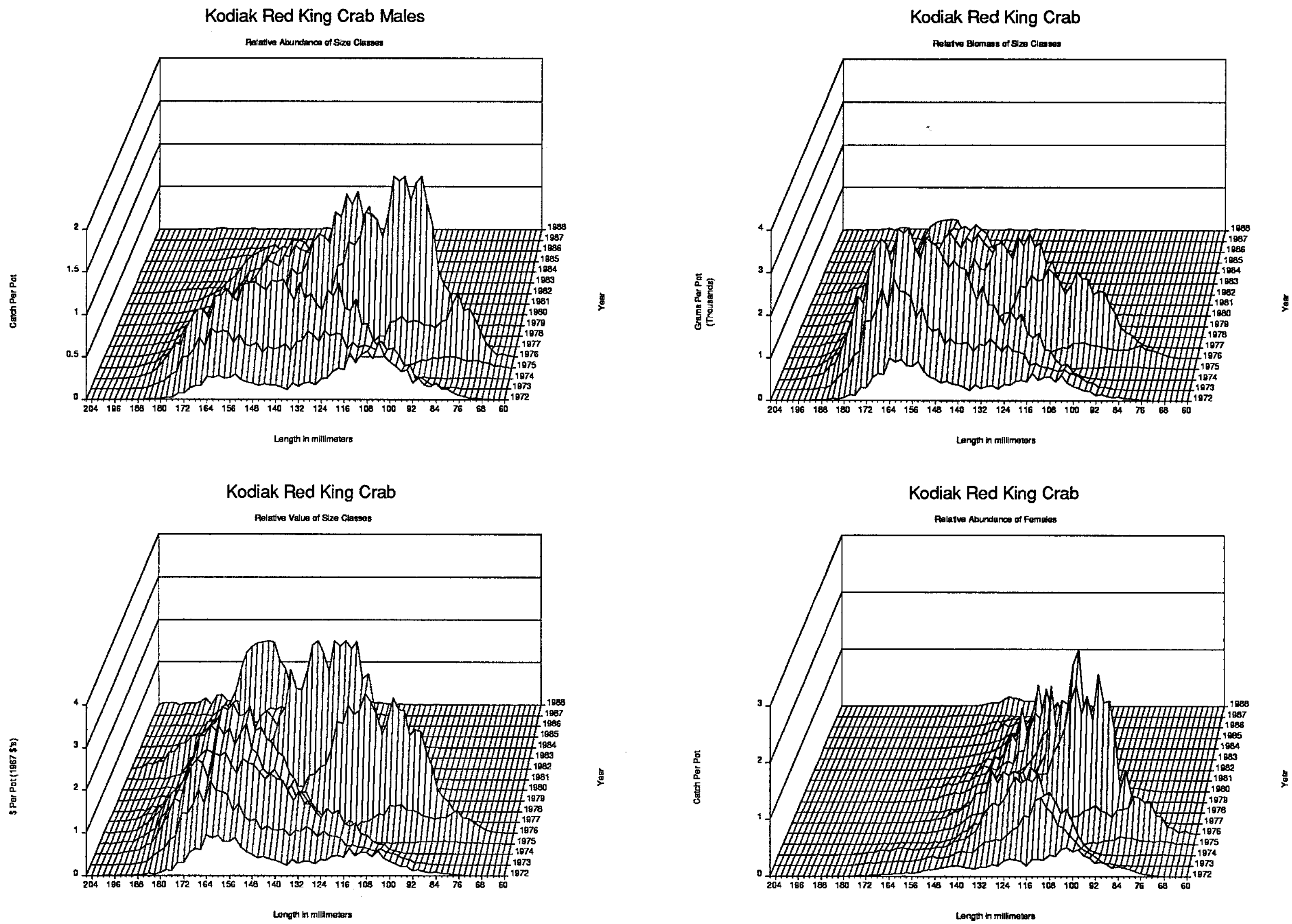

Figure 4. Length frequency data of Kodiak Red King Crab Males as numbers per pot (Upper left), biomass per pot (Upper right), nominal dollars per pot (Lower left). Females as numbers per pot are in the lower right graph. This view shows the early history of the survey in the foreground.

Projected Effect of 3-S Management

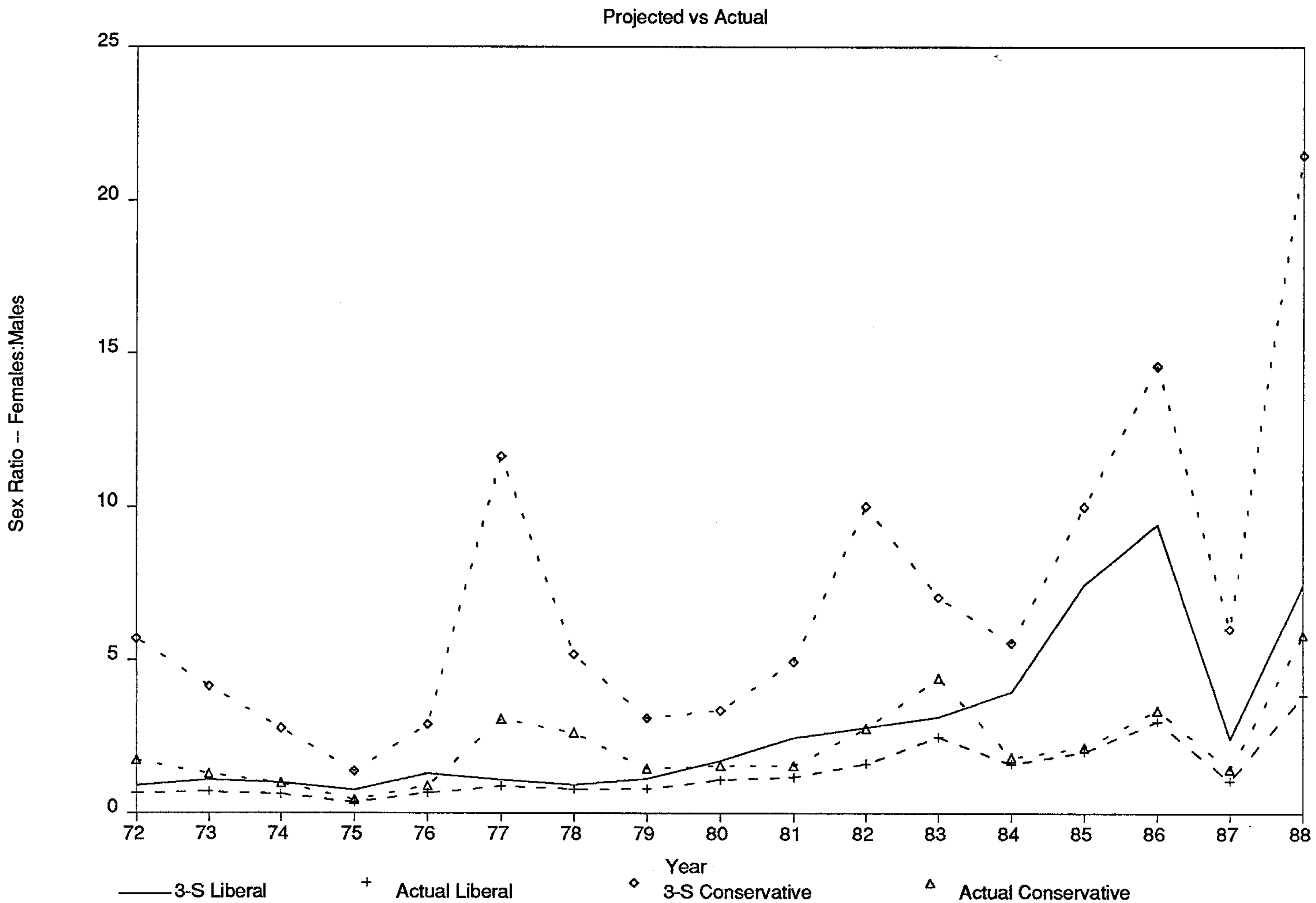

Figure 5. The figure portrays the sex ratio of females to males, which would have resulted from a hypothetical fishery with an exploitation rate of 90% for each year listed. The actual sex ratio which occurred under historic management practices is listed for comparision. Since the actual size of maturity for males is not clearly defined, liberal (small size) and conservative (large size) alternatives are provided for comparison.

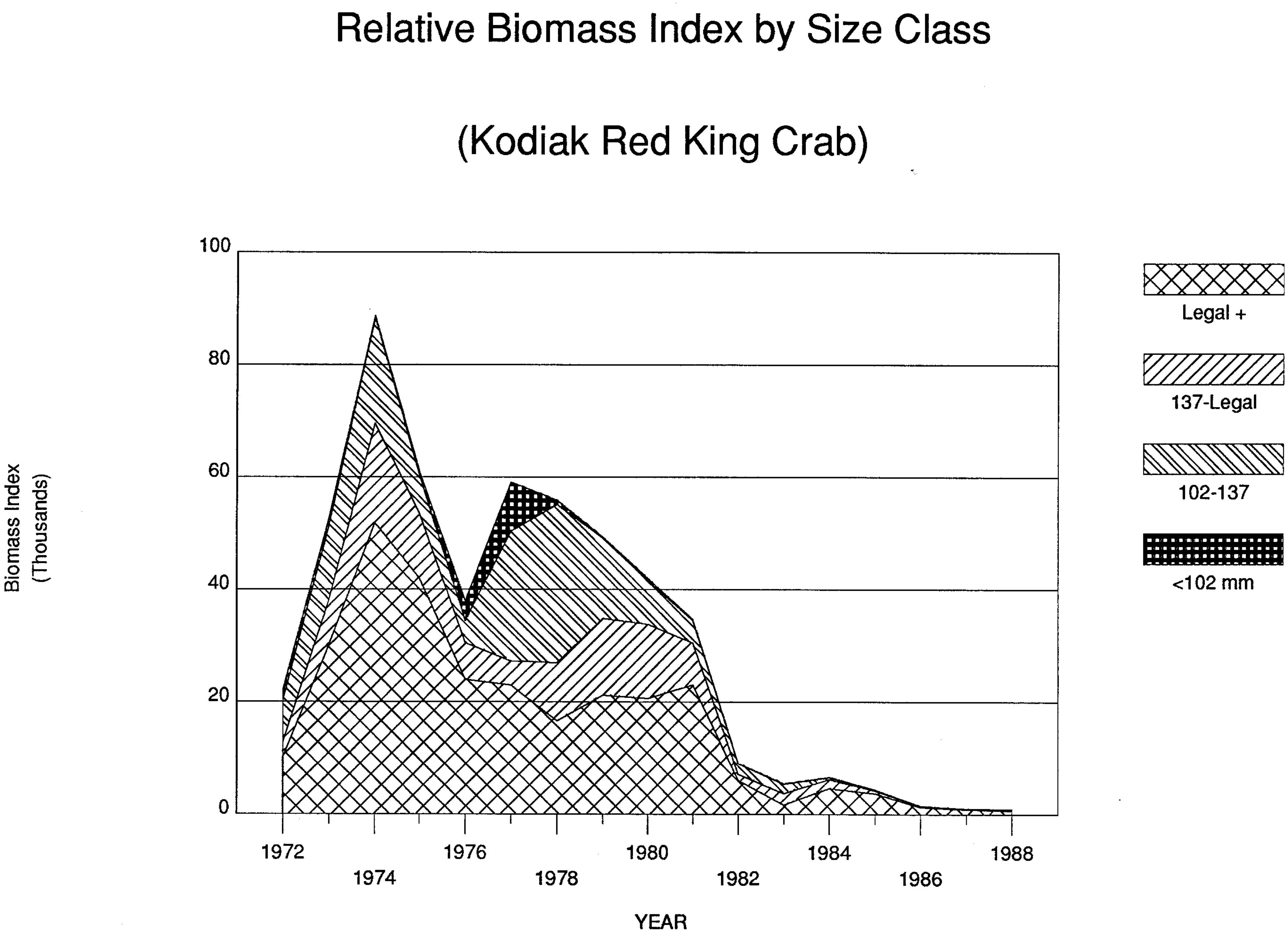

Figure 6. This graph illustrates the relative proportion of the male crab biomass which is greater than legal size. The overall trend of the population is also illustrated by the graph.

THE ROLE OF ECONOMICS IN BYCATCH VALUATION

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ABSTRACT

The fishing gear used in most fisheries, including the groundfish fisheries off Alaska, is not completely selective. That is, it results in the catch of target species as well as other species that are often not intended to be taken. The latter catch is referred to as bycatch because it is a byproduct of the effort to take the target species.

From an economic perspective, the fisheries management objective is often to minimize the cost of bycatch where that cost consists of what will be referred to as the impact, control, and management costs. The impact cost is the cost resulting from restrictions imposed on those who harvest, process, market, or consume the species taken as bycatch. The control cost is the cost borne by a fishery when it takes actions to control its bycatch. Management cost is the cost of management agencies of implementing and enforcing a management measure to control bycatch.

Two methodological approaches used to quantitatively assess the economic impacts of a management program designed to minimize these costs are presented. These are benefit-cost analysis, which includes, as a prerequisite, price response modeling, and input-output analysis. The empirical application of benefit-cost analysis to the issue of halibut bycatch in the groundfish fisheries off the coast of Alaska is discussed, and data needs and limitations are identified.

INTRODUCTION

Although the management of the incidental catch of non-groundfish species in the groundfish fisheries off Alaska has received considerable attention since well before the North Pacific Fishery Management Council was established in 1977, the rapid expansion of domestic participation in the groundfish fisheries has resulted in the incidental catch issue, or bycatch, becoming a more contentious management issue. The Council is currently considering significant and comprehensive changes in the way they manage the groundfish fisheries off the coast of Alaska to better account for and control the bycatch of crab (king and Tanner crab) and halibut.

Catches of species other than the species being targeted is of biological consequence if that incidental catch is of large magnitude relative to the current population, and if that incidental catch is improperly accounted for in the directed fishery for the species. For the most part, however, the incidental catch of crab and halibut in other fisheries is an allocation issue because it can affect the amounts available to the halibut and crab fishermen.

The purpose of this paper is to examine the bycatch issue from the point of view of the value of the competing uses of crab and halibut resources. In doing so we wish to address the following issues:

What is the bycatch problem from an economic perspective?

What criteria will be used to evaluate alternative management measures to control bycatch?

What economic concepts are useful in describing the effects of such management measures?

How can useful estimates be developed for each concept?

What is the appropriate mix of quantitative and qualitative economic information?

What mechanisms will allow better information to be developed and used?

What is the bycatch problem from an economic perspective?

The fishing gear used in most fisheries, including the groundfish fisheries off Alaska, is not completely selective. That is, it results in the catch of the target species or species groups as well as other species that are often not intended to be taken. The latter catch is referred to as bycatch because it is a byproduct of the effort to take the target species.

There are three reasons why bycatch is a contentious management issue. First, bycatch of a species in one fishery may reduce the amount of that species that can be taken in the fisheries that target on it. For example, the bycatch of halibut in the groundfish fishery tends to reduce the amount of halibut that is available to the halibut fishery if the bycatch is retained or if discarded bycatch is subject to discard mortality. Second, a fishery may not be able to control its bycatch without using less productive or more costly fishing techniques. Third, there is not a mechanism in place that tends to assure bycatch will be controlled to the appropriate levels automatically.

From an economic perspective, the solution to the problem is to minimize the cost of bycatch where that cost consists of what will be referred to as the impact, control, and management costs. The **impact cost** is the cost, resulting from bycatch, imposed on those who harvest, process, market, and consume the species taken as bycatch. For example, this would include costs imposed on halibut fishermen as the result of reduced catch due to halibut bycatch in the groundfish fishery. The **control cost** is the cost borne by a fishery when it takes actions to control its bycatch. For example, control cost would include the cost of using more expensive gear to control bycatch. **Management cost** is the cost to management agencies of implementing and enforcing a management measure to control bycatch.

If either the impact cost or the control and management costs did not exist, or if the appropriate level of control would occur automatically, there would be no bycatch problem. Without impact costs there would be no reason to worry about bycatch, other than perhaps for ecological reasons, and in that case the conservation protection of the Magnuson Fishery Conservation and Management Act (MFCMA) would apply. Without control or management costs there would be no problem because the obvious solution would be to have no bycatch. Finally, if there were a mechanism that tended to produce the appropriate level of control, management agency intervention would not be necessary and there would not be a management problem.

If the impact costs were borne by those who impose them, those who take bycatch would tend to control bycatch at the appropriate level and no intervention by the management agencies would be necessary. However, this is typically not the case. Those who take bycatch usually impose most of the impact cost on others and as a result will tend to have an inadequate level of control without such intervention. Therefore, intervention is probably required to balance the three types of costs discussed above.

<u>What criteria will be used to evaluate alternative management measures to control bycatch?</u>

The problem of minimizing the cost of bycatch can be expanded into the objectives of having management measures that are effective, efficient, and equitable. **Effective** measures are those which reduce bycatch to the appropriate levels. **Efficient** measures are those which result in the lowest control and management cost for given levels of bycatch. **Equitable** measures are those which meet some agreed upon standard of fairness.

The appropriate bycatch levels can be determined by a political/analytical process prior to the fishing season, or by a market process during the fishing year. Regardless of which approach is taken, it should be recognized that: 1) the appropriate level for one bycatch species is probably not independent of those of other bycatch species; and 2) the concept of "bycatch needs" is so poorly defined that it is counterproductive.

The efficiency criterion will not be met if a given level of bycatch can be attained at a lower control and management cost by changing either the mix of control measures used by a fleet or the distribution of control effort within a fleet. Much of the information required by a management agency to determine the appropriate mix of control measures and distribution of control effort is not expected to be available to managers. However, there are obstacles to using measures that do not require managers to make such determinations.

What economic concepts are useful in describing the effects of such management measures?

In order to compare alternative management measures in terms of bycatch cost, it is necessary to know which effects of both bycatch and efforts to control bycatch are to be included as costs. Either or both of the two categories of effects can be included.

One category consists of effects that would be included in benefit-cost analysis. Benefit-cost analysis is an economic concept that is typically used to estimate how a particular action will alter the overall economic wellbeing of a nation. The changes in the wellbeing of individual residents or groups of residents is not necessarily considered. This approach is more appropriate from a national perspective than from a regional one.

The other category consists of those effects included in community impact analysis. The economic concept of community impact analysis is used to provide measures of the changes in the level of local economic activity that a particular action will produce. The level of activity is often measured in terms of employment, income, and expenditures. The main reason why such changes are not included in benefit-cost analysis is that the change in economic activity in one community or region is often at the expense of activity in other areas.

How can useful estimates be developed for each concept?

To date only limited attempts have been made to use benefit-cost analysis in evaluating management measures to control bycatch. Typically, an estimate of the exvessel value foregone due to bycatch has been used as a proxy for the bycatch impact cost, and an estimate of the exvessel value that would be foregone if bycatch were reduced by decreasing target catch has been used as a proxy for the bycatch control cost.

The usefulness of such a comparison is in part determined by the validity of the assumption that the only technique used to reduce bycatch is to reduce target catch. Experience has shown that there are a variety of techniques that a fleet can use to reduce bycatch and that when a fleet has an option to do so it will typically use other techniques. This suggests that estimates of control costs based on this assumption will tend to overstate actual control costs. However, without detailed information on the cost and effectiveness of the other techniques, which may never be available to management agencies, it is not possible to determine the extent of this bias.

What is the appropriate mix of quantitative and qualitative economic information?

Ideally, accurate uni-dimensional estimates of the value of alternative uses of a fishery resource would be available to assist in evaluating management measures to control bycatch. For example, if all encompassing and accurate estimates were available of the values of an additional 100 metric tons (mt) of halibut to both the groundfish and halibut fisheries, it would be clear which fishery should receive the additional 100 mt.

The problems are that the information required to make accurate estimates may not be available and there is not a single measure of the value of these alternative uses because value has a variety of components which cannot be added together in a meaningful manner.

As a result of the limitations on the accuracy of the quantitative information that will be available, qualitative information can at times be more useful. The appropriate mix of these two types of information will depend on the accuracy, timeliness, and cost of each; and the appropriate management measures will in part be determined by the mix of information that will be available.

BENEFIT-COST ANALYSIS

Given the above, it is clear that some means of estimating the cost of bycatch, under conditions of limited data availability, is desirable. Fortunately, a methodological approach which can be employed to measure aggregate efficiency changes resulting from management actions, with relatively modest information and data requirements, has been identified. This approach is a modification of the traditional benefit-cost analytical framework currently in wide use as a tool for assessing resource management policy implications. This approach to economic assessment focuses on using resources so as to achieve economic well-being for society as a whole, that is, to maximize social welfare.

Every action, contemplated or taken, involves costs. These include not only direct costs associated with implementation of the specific action, but also costs attributable to **not** taking alternative actions. Likewise, every action, contemplated or taken, also involves benefits. Thus, the objective of any decision-maker is to weigh all the benefits and all the costs of each available alternative to assure the choice taken is the best, that is, most efficient, use of the scarce resources available.

In the case, for example, of actions taken to reduce the Pacific halibut bycatch losses in the groundfish fisheries in the U.S. Exclusive Economic Zone (EEZ), it is necessary to account for all relevant costs and benefits. That is, one needs to evaluate not only the costs that accrue to the groundfish fisheries and benefits which accrue to the halibut fishery, but also the costs and benefits imposed on other users of these two resources. To be precise, the goal of the benefit-cost analysis is to comprehensively measure the net change in society's total welfare resulting from a given action.

For purposes of exposition, imagine the economic system as a network of integrated individual markets at various levels. In each market a relationship exists between suppliers of a good or service and those wishing to obtain that good or service, that is, demanders. Each supplier responds to signals from the demanders in this market, but in addition, to varying degrees, to signals from other markets. Likewise, demanders respond to signals from suppliers in their own market, but also incorporate information from other markets in the system in making their economic decisions (Figure 1).

Taking the U.S. fishing sector which deals with Pacific halibut as an example, the fisherman (exvessel supplier) offers his product to the processor (exvessel demander) for sale. While both interact in the exvessel market, both are simultaneously influenced by other markets in the broader system. Specifically, the fisherman who is the "supplier" at exvessel, is the "demander", in a sense, at the fisheries administration level as fishery management regulations dictate the "supply" of halibut that will be made available to the fisherman for harvest.

In the same manner, the processor is the "demander" in the exvessel market, and the "supplier" in the first wholesale market, and so it goes from exvessel, through all the intermediate markets of the system, to the final consumer. Each level of the market functions in response to internal signals, but also, to varying degrees, to outside signals. Therefore, the process of evaluating the aggregate change in social welfare (net costs and/or benefits) from a given action affecting price and/or quantity, must account for these multiple markets and the feedback mechanism which interconnects them.

In general, one means of doing this is to estimate demand and supply relationships for each and every market level of the economy affected by a given action. Having estimated these demand and supply relationships, it is then theoretically possible to accurately measure the change in economic welfare attributable to the subject action by evaluating the net change in the area below the demand curve or above the supply curve in each relevant market.[1] As a final step, one may sum the resulting individual changes over all affected markets to obtain an aggregate measure of the total welfare effect of the action.

The principal limitation of this approach is the quantity and quality of data needed for the analysis. Specifically, detailed information concerning price and quantity responses for each and every affected market is necessary to evaluate individual market changes, and to allow subsequent summation of these changes into an aggregate welfare measure.

Typically, such detailed data are not available and cannot be readily compiled. Thus, this approach, while technically acceptable, does not offer a reasonable option for actually assessing the welfare change, that is the benefits and costs, of a specific action. Use of this approach will

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[1] Within an error of approximation as outlined in Willig 1976.

necessarily require gross speculation about relationships in affected markets, and use of assumptions in place of observable data. The resulting output of such an undertaking cannot be argued to be, even in an approximate sense, a measure of the actual social welfare change attributable to the subject action.

Having drawn this conclusion, what is left?

Fortunately, economic theory establishes that, under reasonable market integration assumptions and using "general equilibrium" demand and supply relationships, it is possible to accurately measure the change in society's welfare by measuring the area of change under the demand curve and above the supply curve in **any one** of the several integrated market levels affected by the subject action.[2] That is, if one considers general equilibrium demand and supply curves (schedules which formally account for the market adjustments described above), and if the integrated markets are relatively "competitive" in nature, then it is possible to accurately measure the **total** social welfare change, attributable to a given action, in any **single** market of one's choosing within the integrated market system. Fortunately, equilibrium curves are the type observed in time series market data on prices and quantities traded.

This is a very important and powerful conclusion. Unlike the first method cited above, which requires careful measurements of every single market relationship impacted, and then aggregation of these several market welfare measures, the general equilibrium approach permits the analyst to evaluate the **aggregate** change in net social welfare in a single market, of his or her choosing. Clearly, estimating demand and supply relationships in a single market is far less costly (in the sense of data required and potential measurement errors), and allows the analysis to be conducted based upon the strongest data set available. In commercial fisheries analysis, this flexibility to adapt the empirical measurement to the available data, without loss of confidence in the results, is very desirable.

From both a theoretical and empirical perspective then, the general equilibrium approach to measurement of aggregate welfare change is superior to the sequential procedure described earlier. Furthermore, at least for Pacific halibut, recent research, provides the necessary demand coefficients to permit the estimation to be made for Pacific halibut (Lin et al., 1988). In Section V we provide a benefit-cost analysis (as well as a price-response analysis to be described below) of a proposed change in the amount of halibut that can be taken as bycatch by groundfish fisheries in the Gulf of Alaska. Similar demand and supply estimation is necessary for groundfish, however, to present a complete picture of welfare change associated with bycatch reduction.

There remains an additional complication associated with commercial fisheries in the U.S. EEZ, common to both methodologies, which must be

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[2] See, for example, *Applied Welfare Economics and Public Policy*, Just, Hueth, and Schmitz, 1982, Prentice-Hall, Englewood Cliffs, NJ.

recognized and overcome before uniform adoption of a welfare measurement technique in these fisheries can be advocated. This involves the question of "what is to be counted as a benefit and/or cost?" In the Pacific halibut example described in the "general equilibrium" approach, the vertically integrated market was principally comprised of wholly U.S. market sectors. That is, for the most part, U.S. citizens harvested, processed, marketed, transported, distributed, retailed, and consumed the product. Thus, a welfare measurement made in any single market component of the integrated network would correctly capture the total aggregate welfare change for all suppliers and demanders in the U.S. economy. However, to the extent that the analysis is limited in scope and interest to addressing only U.S. social welfare changes, any of the market levels in the chain which are not wholly contained within the U.S. economic network will capture welfare effects which accrue to foreign interests involved in the commercial fisheries sector, and will therefore bias the impact estimate for the U.S. It is then necessary to measure and deduct the welfare changes accruing to non-U.S. sectors from the total welfare change to isolate the domestic impact of a subject action.

Alternatively, because welfare measurements at each and every level of the market can always be further divided into "consumer surplus" (the area above price and below the demand curve), and "producer surplus" (the area below price and above the supply curve) (Figure 2), it is possible to circumvent the need to measure welfare changes in foreign markets (potentially a very difficult and complex task). It is proposed that, for example, in the case of a fishery that involves U.S. harvesting, foreign primary processing and transshipment, and exportation of an intermediate product from the foreign nation to the U.S., the following approach be taken.

First, measure the subject welfare change at exvessel as the change in the area below the price(s) and above the relevant supply curve. This change will capture the total U.S. "producer surplus" (perhaps equal to zero) associated with the subject change. Moving now to the point in the vertically-integrated market system at which the intermediate product reenters the U.S. market, one would estimate the change in the area above the price(s) and below the relevant demand curve in that market. This measure accurately captures the total welfare affect of the subject change for all market levels above and including the one in which the product reenters the U.S. By summing these two measures an accurate aggregate welfare measure can be obtained which includes **only** U.S. welfare changes, i.e., U.S. costs and benefits.

An example may help to clarify the principal issues of concern. To the extent that all fisheries in the EEZ were completely domestic from harvest to consumption, there would be no need to depart from the general equilibrium methodology. However, joint-venture fisheries, as well as DAP operations with substantial exports, require a modification of the approach if, indeed, one wishes to limit the welfare measure exclusively to the United States. In the current U.S.-U.S.S.R. yellowfin sole joint-venture U.S. fishermen harvest the catch, then deliver it to Soviet vessels for processing and export. Seemingly, the welfare effects for the U.S. end at the point of the exvessel transaction. However, while yellowfin sole delivered to the Soviets does not re-enter the U.S. fisheries sector, the

Soviets do exchange king crab for yellowfin sole, in lieu of cash payment. This king crab is subsequently processed, transported, distributed, marketed, and consumed within the U.S. seafood sector. This would seem to suggest that limiting the welfare measurement to the exvessel level, in this case, misstates the true welfare implications for the U.S.

An even more direct example of this empirical complication is exhibited by the market for joint venture caught pollock. Korean joint-ventures involve U.S. harvesters delivering to Korean vessels for primary processing and shipment to Korea. The resulting block product is subsequently exported from Korea to the U.S. where it is reprocessed, distributed, and finally consumed by U.S. households. Clearly, failure to account for the reintroduction of this joint venture product into the U.S. market would result in errors in U.S. welfare measurement.

As a third example consider the Japanese joint-venture arrangements wherein U.S. fishermen harvest pollock which is processed into surimi, transshipped to Japan, then exported back to the U.S. for further processing as analogue products for U.S. consumption. Again, while some of the markets between exvessel and final consumer are outside the U.S. economic sector, several are not, making it incorrect to attribute the benefit-cost impacts of an action affecting these fisheries, measured at one market level, as a measure of a net change in benefits to the United States.

This discussion suggests that the estimation of aggregate welfare impacts for the U.S. economy, resulting from a given fisheries management action, is complex, but possible. Correct answers will depend on careful and rigorous systematic application of the available theoretical knowledge about welfare economics as well as a complete understanding of the U.S. EEZ commercial fisheries context within which the problem resides. Economic theory provides the means to estimate these benefit-cost impacts.

The challenge will be to either develop the data needed to support the analysis and then to assure that the methodology is understood and carefully applied and interpreted or to develop management measures which can be successfully implemented without such information.

PRICE RESPONSE ANALYSIS

Although benefit-cost analysis as outlined above may be the primary tool for assessing whether the U.S., as a whole, is better or worse off following a change in fisheries management or a reallocation of a species between bycatch and target fishery use, managers are, of course, also interested in whether or not prices may change as a result of the action, and if so, in what direction, and how much.

As argued above, multi-market benefit-cost analysis, whether it is done at the individual market level and then aggregated, or conducted in a single market using general equilibrium approaches, involves estimation of demand and supply relationships or schedules. Simply put, these schedules describe how the buyer and seller adjust the amount they are willing to purchase or produce, given changes in the price of the good (assuming all other factors which influence these relationships are held constant).

This means that in order to do a benefit-cost study one must understand the quantitative relationship between price paid and quantity purchased or supplied. Therefore, information concerning predicted price response to the subject action is a prerequisite of the benefit-cost study.

To better understand these price response models consider the example shown in Figure 3. The retail demand schedule for a species of fish is represented by the line labelled "Demand", and the retail supply schedule for the species by the line labeled "Supply". The market is said to be **in equilibrium** when the amount demanded by consumers and the amount supplied by the retailers is equal. In this example this occurs when price is $4.00 per pound and quantity is 16 million pounds. Thus, the prevailing, or **market clearing**, price is $4.

If the supply shown were to decrease (for example, due to increases in the amount of the species taken as bycatch) the market clearing price would be expected to change. For example, using the relationship shown, if supply were to decrease by 2 million pounds, the market would reattain equilibrium with a price of about $5 per pound.

It is therefore possible, using this kind of quantitative approach, to provide answers to the questions of the direction and magnitude of any possible price response to proposed changes in management measures (including changes in the way bycatch is allocated).

COMMUNITY IMPACT ANALYSIS

Economic impact analysis is the study of economic activity generated by expenditures on purchased goods. Evaluating the total economic impact of, for example, a proposed change in fisheries management strategy would involve the following steps: (1) compute how much economic activity is generated by the current level and pattern of expenditures; (2) compute the economic activity that would result under the proposed new management regime; and 3) subtract the two to find the net economic impact (effect) of the new management strategy. Such analysis requires knowledge of how much money is being spent on fuel, food, equipment, wages, etc. in **each local area** and how this money is respent in the local area and **outside** the local area.

One way to do this would be to survey everyone who took part in the spending and respending in the local and non-local areas and then add up all these expenditures. One would summarize the results by saying something like, "An expenditure of $1 in Sitka generates $2 of economic activity in the Sitka area." The ratio of total economic activity to initial expenditure is called the **multiplier**. In this example, the total multiplier is 2.

To complicate the issue, however, there are at least three types of multipliers. The first has been described above, and is called an **output or sales multiplier**. Such a multiplier is used to describe the total effect in sales brought about by an initial expenditure in the basic sectors of the local economy (timber, fisheries, tourism, agricultural production, mining, etc.). In the example above, "2" is the output multiplier. It implies that for every $1 spent in Sitka's basic industrial sector, $2 of total spending will occur within the community.

An example of the pattern of spending and respending in a local economy and how that pattern is used to determine a multiplier is shown in Figure 4. The left most column, (A), represents an initial expenditure of $1 in a basic sector, for example, the fishing sector, where the $1 is money received by the fisherman for his catch (<u>exvessel revenue</u>). At the second spending level, (B), 40 cents is spent locally and 60 cents is spent outside the local area. The 60 cents spent outside is lost to the local economy and is called <u>leakage</u>. In a similar way, expenditures in the local economy continue to occur (C through F) until the effect of further respending is too small to measure. Totaling the money spent locally at each round of spending yields a total of $1.66 generated by the initial expenditure of $1.00 hence the output multiplier is $1.66/$1.00 or 1.66.

The output multiplier measures sales and is important in the "big picture", but if we are asked to answer questions about the local effects of sales on income and employment we need to look at other kinds of multipliers. The second kind of multiplier is the **income multiplier**. This multiplier is generally smaller than the output multiplier and is estimated in essentially the same way as described above except that personal income effects are examined. For example, if the initial expenditure is $1.00, 60 cents may be realized as income by the fisherman. At each level of expenditure some portion of the locally spent money will be received as income (wages or salary) while the remaining portion is not income generating. In the same way that output expenditures were totalled for the output multiplier, incomes received are totaled. Let's say the total income received by all industries in Sitka from the expenditure of the original $1 is 90 cents. The income multiplier is therefore 90 cents/60 cents or 1.50.

The third multiplier looks at the input-output relationships in a local economy from yet a different perspective. The third multiplier is called the **employment multiplier** and represents the total impact on the numbers of jobs in a community. For example, if the employment multiplier is 2 the addition of one job in a basic sector, such as the addition of a crew member to a fishing boat, will result in a total of two jobs added to the local economy (an addition of one job beyond the harvesting sector).

An analysis of economic impact will examine and report all three types of multipliers. This gives the fisheries manager the ability to examine the consequences of a proposed fisheries management strategy from three perspectives: total sales, personal income, and employment.

Such an analysis is known as **input-output analysis**. An input-output model is constructed from a survey of businesses in an area. The survey collects information on all transactions that each industry conducts and then summarizes those transactions for each industrial sector. The information is manipulated so as to produce a matrix of numbers which describe the input and output relations in each industrial sector. Fortunately, an input-output model of an economy can be constructed once and, as long as the basic structure of the economy remains unchanged, be used again and again in analyzing the impact of a change in expenditures.

Unfortunately, there are no current up-to-date input-output models available that are sensitive to changes in Alaskan fisheries performance. This situation may be partially rectified this fall when Alaska Sea Grant completes development of a new input-output model for the Alaskan fisheries. The model will be interactive, which means the user will be able to change the pattern and amount of landings in various ports in Alaska (and Seattle and the northwest) and then examine the change in economic activity from all three perspectives mentioned above: total output, income, and employment. Note that these results will be specific to the local area examined. Thus, for example, a particular area may be effected positively by the proposed change and another area negatively impacted. The managers job will be to weigh these kind of distributional effects against the results from the overall perspective of the benefit-cost analysis.

Value added and Turnover

Having set out what multipliers are and how they are derived from input-output analysis we should point out what multipliers are **not**. Two terms are often used incorrectly in discussions of multiplier effects. These are **value added** and **turnover**. Value added represents the increase in value imparted to a product as it moves through the processing chain. For example, consider a fisheries product which is filleted, frozen, shipped to Seattle, held in inventory by a distributor, and is later taken out of storage, thawed, packaged and finally placed on the supermarket shelves. If the fish originally brought $1 in exvessel value and sold for $4 then the value added is $3 dollars. Value added is a useful concept in that it represents a contribution to the gross product of the economy. However value added has nothing to do with any of the multipliers defined above. It is therefore incorrect to say, using the numbers above, that the multiplier effect is $4/$1 or 4.

The same kind of warning applies to the use of the term "turnover". Turnover represents the number of cycles of spending and respending. In the example shown in Figure 3 the number of spending cycles was 6 (A through F). Turnover is useful, therefore, in telling us something about the structure of the local economy. However, the fact that the turnover is, in our example, equal to 6 has nothing to do with the magnitude of any of the three multipliers defined above.

AN APPLICATION TO HALIBUT BYCATCH

This section provides an example of how the benefit-cost approach described above might be used to provide some insight into the valuation of the effect of an increase in the allocation of halibut as bycatch to the groundfish fishermen in the Gulf of Alaska. This reallocation is currently being debated prior to submission to the Council for attention in 1989. This preliminary analysis, therefore, could be used to provide guidance on the efficacy and allocative effects of adoption of the proposed action.

Unfortunately, data limitations, as well as incomplete knowledge of the quantitative relationships necessary for a complete benefit-cost analysis, limit our examination to a partial look at the economic consequences of such an allocation. Specifically, we do not have quantitative estimates of the relationship necessary to compute management costs or the reduction in control costs that would be realized by the groundfish fleet. Therefore, given an estimate of halibut ex-vessel demand, we calculate the impact cost of the increased halibut bycatch, that is, the cost to the harvesters of halibut. Of course, since we are examining a quantitative relationship between landings and price we can also say something about the expected change in the ex-vessel price of halibut.

<u>The model</u>

Lin, Richards, and Terry (1988) have estimated a price-dependent ex-vessel demand for halibut using annual data from 1955 through 1984, as

$$\ln EVP = -0.11 - 0.34 \ln LBS + 0.24 \ln DAY - 0.35 \ln CSH + 0.87 \ln WPIF \tag{1}$$

where ln indicates the natural logarithm of the variables

- EVP - real ex-vessel price, \$/lb;
- LBS - landings of halibut, millions of pounds;
- DAY - the length of the halibut season in days;
- CSH - cold storage holdings in pounds; and,
- WPIF - real wholesale price of all finfish.

Given the log-log specification, all variable were scaled by their geometric means. Substituting those means into equation (1) and assuming that all variables other than landings and price remain fixed, (and that the estimated relationship adequately describes future behavior) yields

$$\ln EVP = 1.8994 - 0.34 \ln LBS, \tag{2}$$

or, in exponential form,

$$EVP = 6.6818\ LBS^{-0.34} \tag{2'}$$

<u>An application</u>

In recent years the Council has attempted to manage the groundfish fisheries of the Gulf of Alaska so as to limit halibut mortality in the groundfish fisheries to 2,000 mt annual mortality. It has been proposed that this mortality ceiling be increased by 750 mt to allow longline fishermen targeting on groundfish increased catches of the target species, sablefish and Pacific cod. This mortality increase, if adopted, would be formally accounted for by the International Pacific Halibut Fishery Commission (IPHC), the body that regulates the halibut fishery, such that this increased mortality (subject to conversion to adult equivalents and processed weight) is used to reduce the next year's allowed quota.

In this case, an increase in halibut mortality of 750 mt translates into a reduced directed harvest of 1.96 million lbs which in turn, according to equation (2'), would indicate that ex-vessel price would subsequently increase from $1.58 to $1.60.[3]

We can therefore complete our partial benefit-cost analysis, concluding that ex-vessel price will increase by approximately $0.02 a pound, that the apparent gross ex-vessel revenue lost to the halibut fishery of $3.136 million (evaluated at original price) will be offset to some extent by this price increase such that the actual revenue lost will be $3.115 million (a difference of $21,000). The actual welfare lost to halibut fishermen relates to foregone profits, not revenue. To examine that part of the benefit-cost accounting one would need to know the supply or cost function relationship for the production of halibut. If the fishermen's marginal costs do not change the profit foregone will be approximately equal to the profit margin ($/lb) times the lost supply.

Assuming that the halibut taken as bycatch are not sold (current regulations require immediate discard of any incidentally caught halibut), all other consumers of halibut, that is, processors, wholesalers, retailers and final consumers, would experience a net loss of welfare of $1.06 million due both to the decreased supply of halibut and the increased price.[4] This information is presented graphically in Figure 5.

Recall that these estimates describe the impact cost only. A complete benefit-cost analysis would include an accounting of the gains to the groundfish fleet, presumably due to increased catches, and hence, revenue and profits. Whether these gains offset the losses in the halibut markets will determine the ultimate attractiveness of the proposed change in management.

CONCLUSIONS

This paper has described the management of bycatch from an economic perspective, focusing on the impact, control, and management costs associated with various allocations of the species as incidental catch or target catch. This perspective leads to a benefit-cost approach where market relationships may be used to assess the net change in social welfare resulting from a reallocation of the species among competing users.

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[3] Price and quantities used to derive these estimates are taken from the IPHC Annual Report, IPHC, 1988.

[4] The solution is obtained by calculating the shaded area shown in Figure 5. The values is most easily derived by inverting (2') so that pounds landed is a function of price and then integrating the inverted function over the price change interval, $1.58-$1.60.

We close with an admonition to managers that although the theory discussed above can be empirically applied to current fishery management problems, data limitations, and imperfect understanding of the technical relationships in the fisheries, particularly information concerning the cost of avoiding bycatch (relocation, changes in gear technology, changes in target fisheries), greatly limit our ability to fully quantify the economic tradeoffs associated with bycatch management.

We should keep in mind that good old horse sense in the market place is the ultimate determinant of behavior. This means that our quantitative tools, as insightful as they may be, can never be expected to outguess a well functioning market, and that, because of this, one promising direction for management is that which provides a framework which allows this optimal free market solution to exist.

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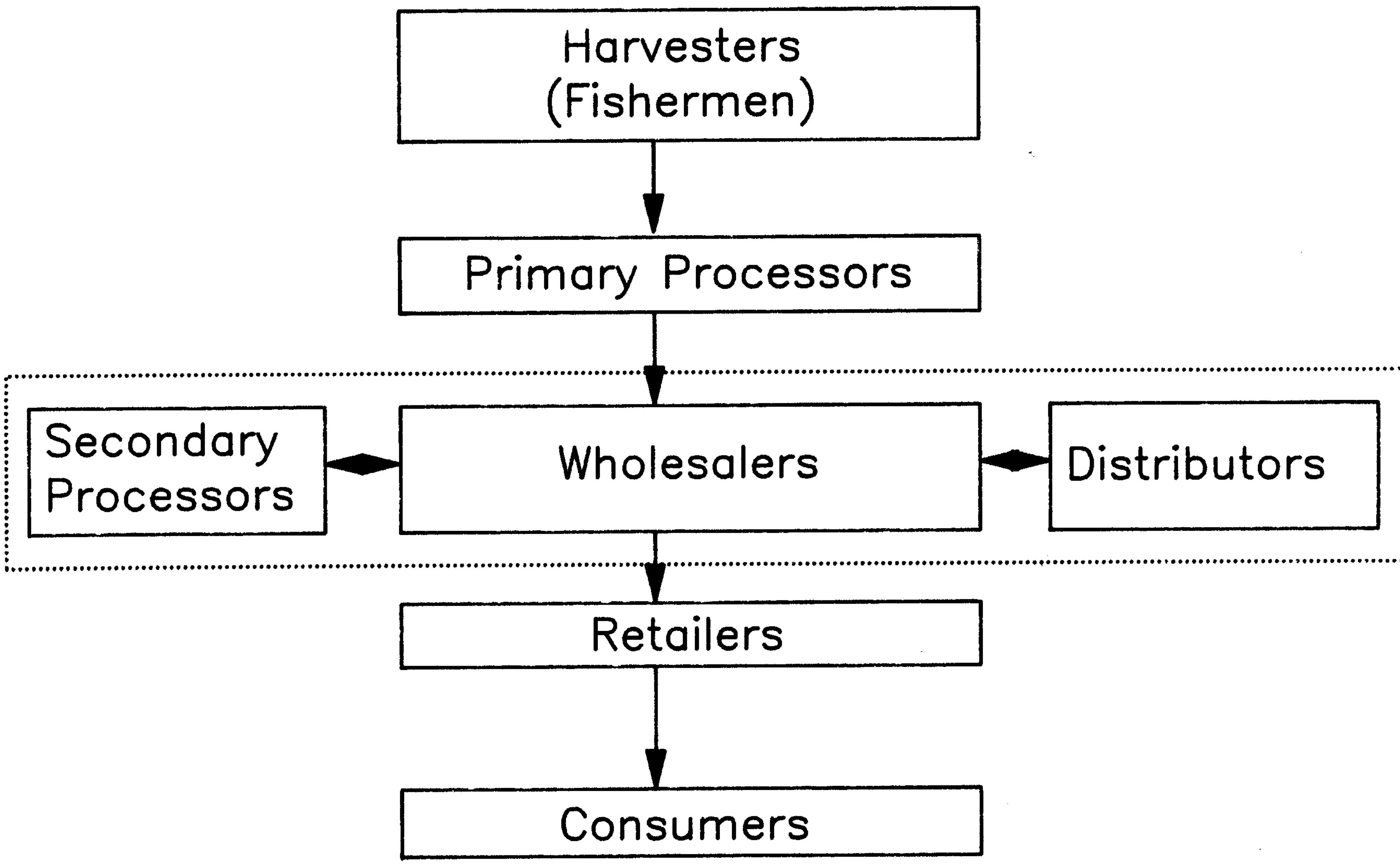

Figure 1. Market levels and relationships in the seafood industry.

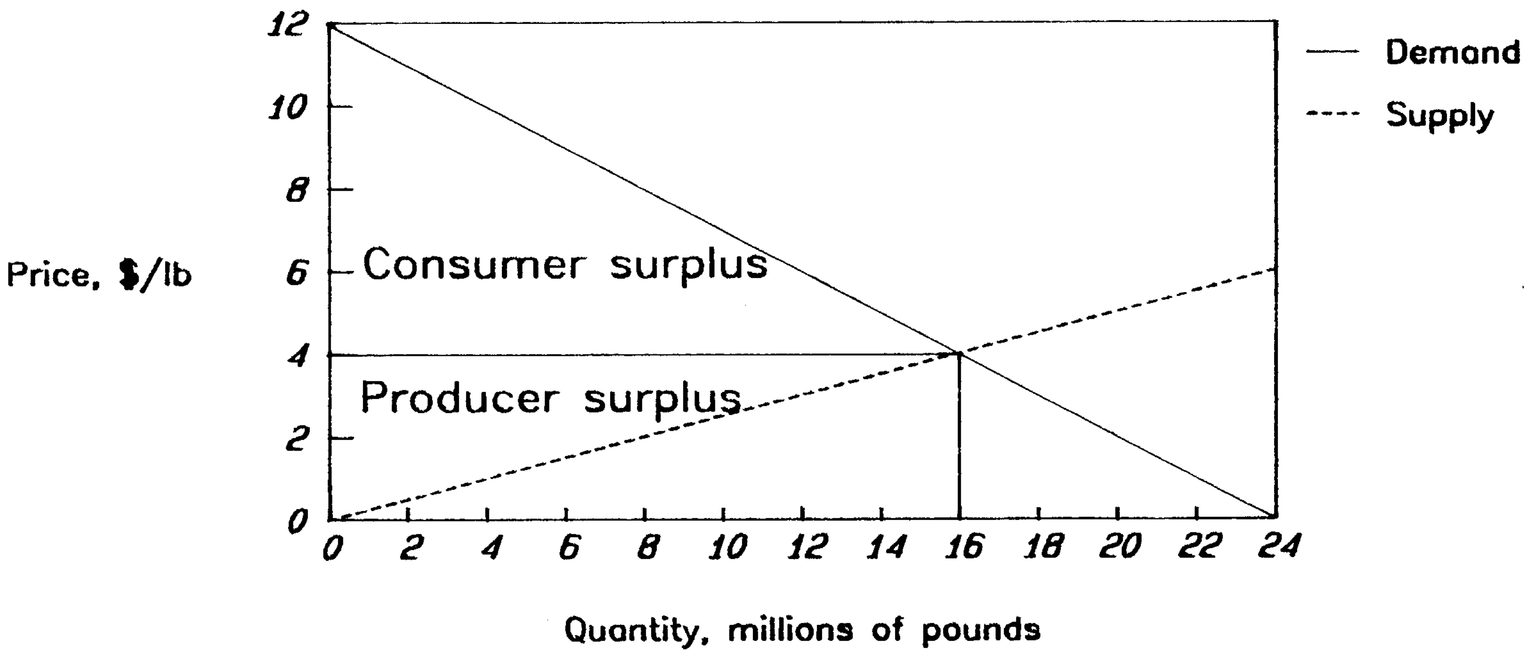

Figure 2. Demand and supply curves including consumer and producer surpluses.

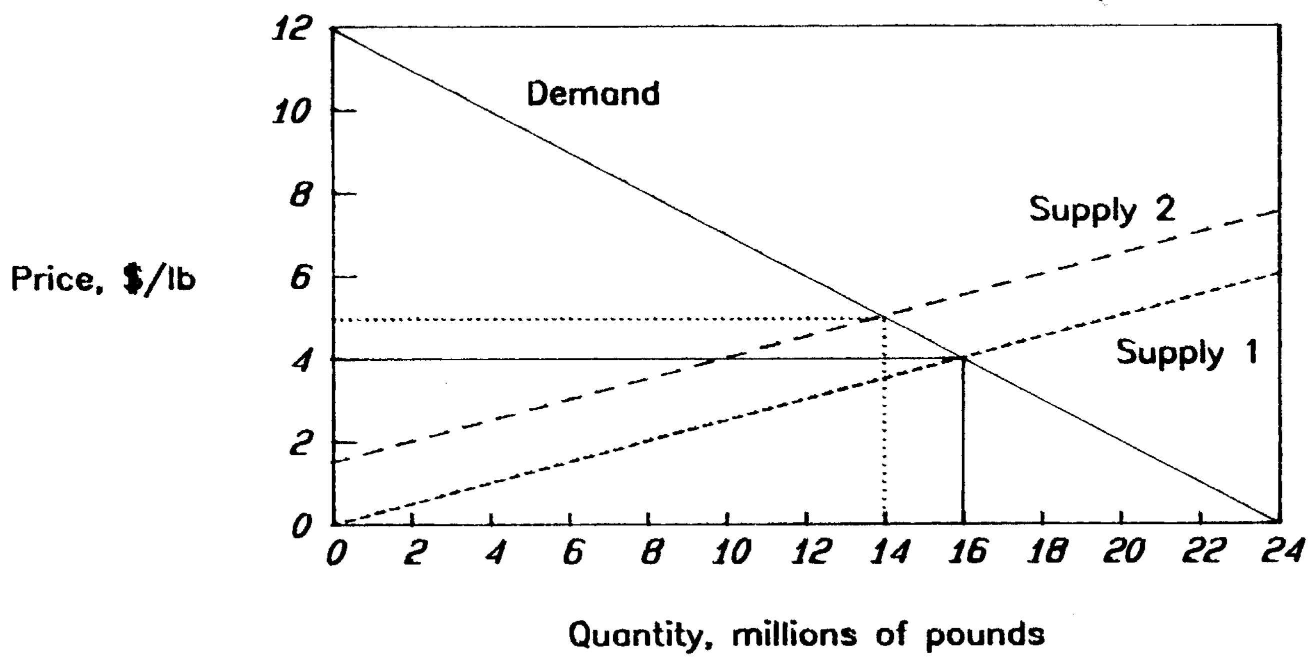

Figure 3. Equilibrium price (market clearing price) with supply shift.

In order to determine the total multiplier value, the initial dollar is added to the sum of local respending. In this example, the multiplier equals 1.66 ($1.00 + 49¢ + 16¢ + 6¢ + 3¢ + 1¢). Thus, $1.66 of local business activity will be generated for each dollar that enters the local economy.

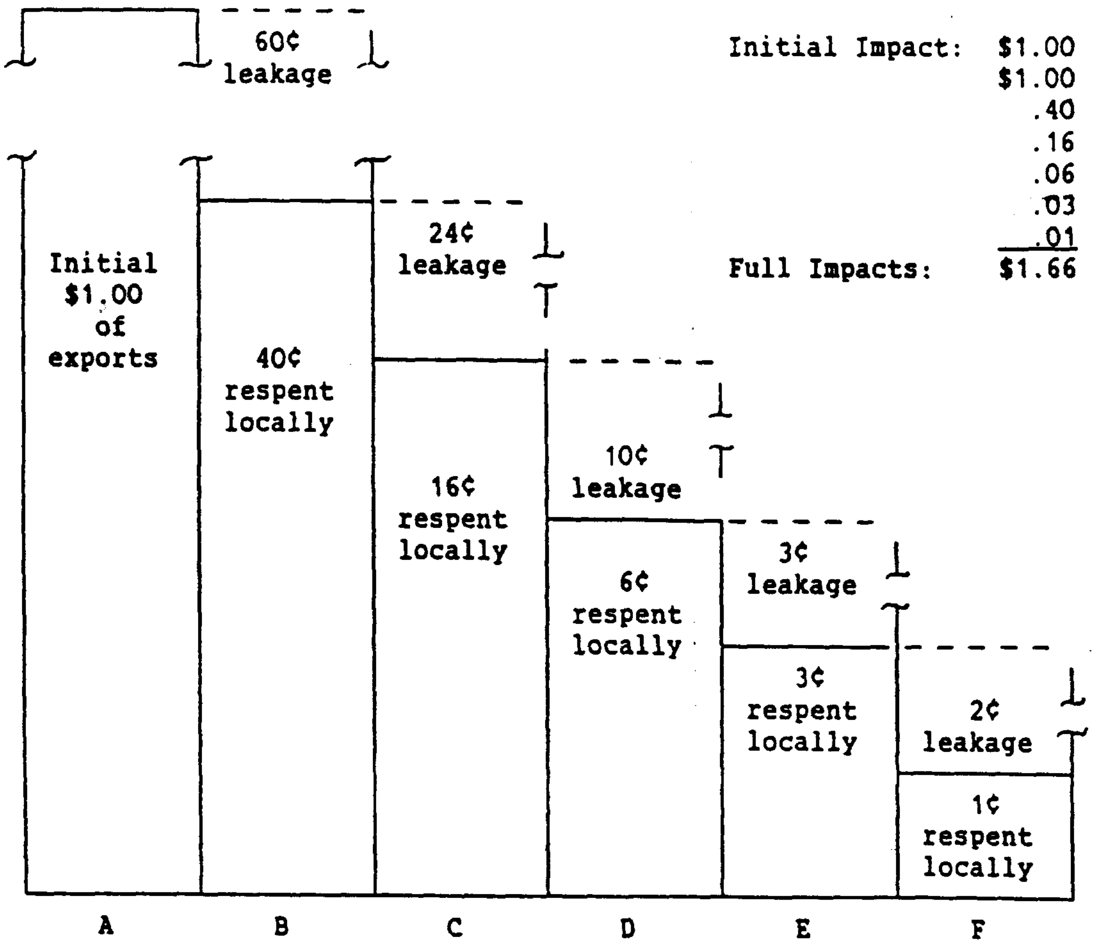

Figure 4. The (output) multiplier effect in a local economy, taken from: Carter, Chris 1985. "Progress report on the economic aspects of the recreational/commercial allocation of coho salmon in the ocean fisheries." Oregon Dept. of Fish & Wildlife. p. 19.

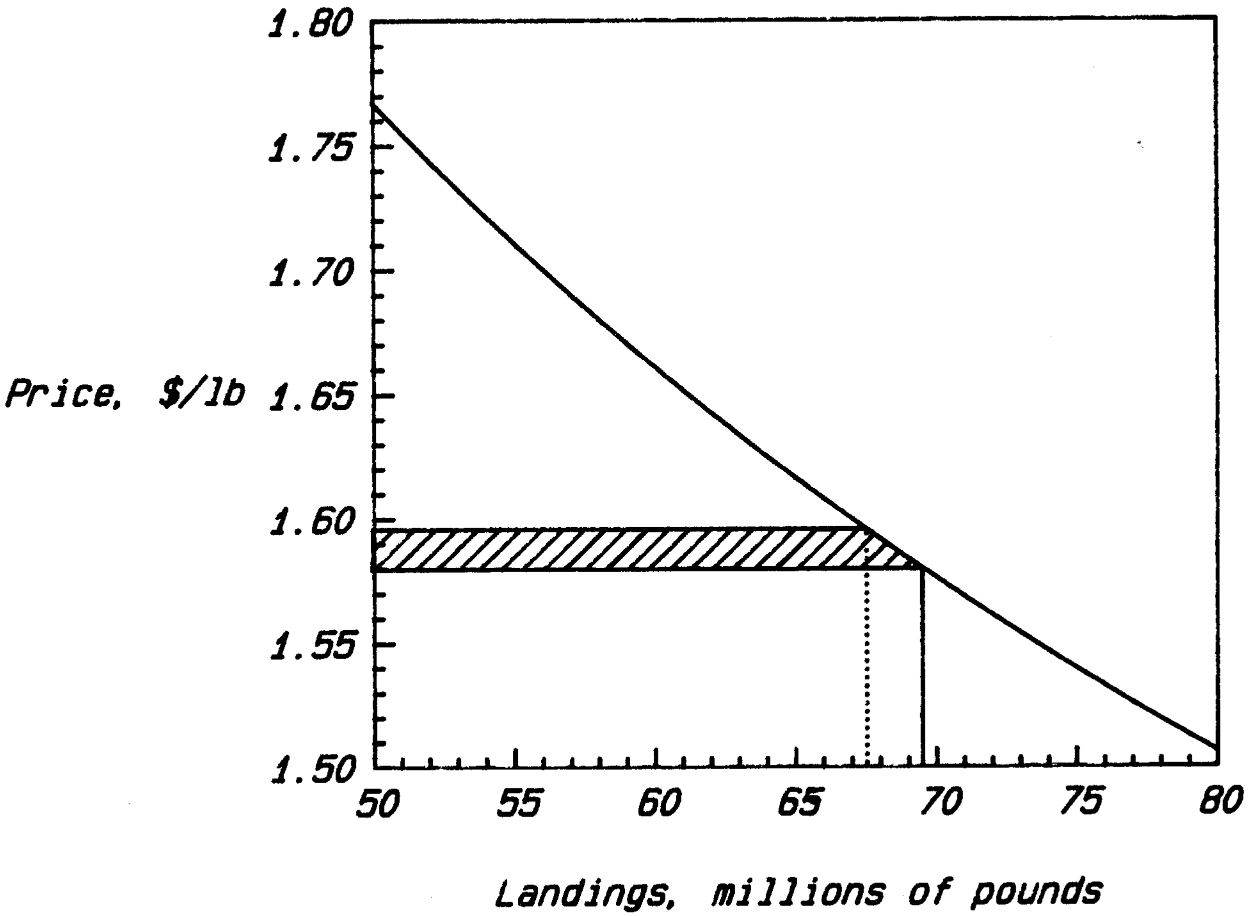

Figure 5. Ex—vessel demand for Pacific halibut and change in consumer surplus.

INDIVIDUAL FISHERMAN'S QUOTAS AND FISHERIES VALUES

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INTRODUCTION

The value of a fishery depends, to a great extent, on the rules that govern the harvest. These rules may include the formal laws or regulations of a government with jurisdiction over the fishery, or they may be less formal, but meaningful, rules that are part of the culture of the fishing community. This is true whether value is interpreted as economic benefits provided to society, the achievement of a particular distribution of those benefits, or the achievement of a less tangible cultural or conservation ethic.

Individual fisherman's quotas are a relatively new type of rule being used to manage fisheries, and in many cases they appear to offer the potential for considerable increases in fisheries values.

In an individual quota program, the total allowable catch from a fishery is divided up among a group of fishermen. Each fisherman receives a portion of the total allowable catch which is his to harvest. He is not allowed to take the part of the total allowable catch given to other fishermen unless the program rules provide some means, such as administrative reallocation or private sales or leases, by which he can gain access to it.

These individual quotas might be reassigned annually to the eligible fishermen according to allocation criteria, or the fishermen might get the right to the quota for a number of years, or permanently, at the time it is first allocated.

A fishery might have a total allowable catch of 100,000 metric tons, and there might be 100 fishermen with entry permits allowing them to fish. Under an individual quota program each of these fishermen might be given an equal share in the total allowable catch. Each would thus receive 1,000 tons of the allowable catch to harvest. Other initial allocation criteria, such as allocation based on historical catch, might also be used, and could lead to a different distribution of quota. If quota can be sold or leased, the actual distribution of quota might also change from the initial distribution through time.

POSSIBLE BENEFITS OF INDIVIDUAL QUOTAS

The possible benefits of individual quotas can be seen by examining a hypothetical fishery managed with and without them. This example has been created deliberately to show the possible benefits that might flow from individual quotas, but it is similar to situations in some important Alaskan fisheries, notably the longline fishery for halibut. Some alternative possibilities are discussed in the next section.

At first, this hypothetical fishery operates without any limit on the total amount of fish that may be caught in a year. Regulations control the amounts and types of vessels and gear that fishermen may use, restrict the effectiveness of those inputs, or limit the minimum size of the fish fishermen may capture.

At some point, fishery managers come to believe that these regulations are no longer satisfactory and they introduce a total allowable catch, or limit on the aggregate harvest. In the short run this reduces catches. In the long run it allows the fish stock to rebuild and ultimately permits fishery managers to raise the allowable catch above the original levels.

When the allowable catch is raised to its new level, the fishery is assumed to be very profitable for those in it. This will prompt new fishermen to enter or existing fishermen to expand their operations.

As fishing effort increases, because of new entry and the expansion of existing operations, any given allowable catch is likely to be taken more quickly. Because of competition between fishermen to capture the fish in a limited time, a fisherman who wants to get his share of the fish will have to continue to increase the amounts of labor and capital that he uses in the fishery so as to get his share of the harvest before the allowable catch is taken and the fishery is closed.

As a result of these labor and capital increases, the season is likely to continue to become shorter. So long as the fishery is profitable, the shortening season and the increasing use of labor power and capital act and react on one and other. The process will continue until, or after, the profits have gone out of the fishery, or until the government intervenes with new, more restrictive regulations.

Shorter seasons can have a number of unattractive effects.

As the season shortens, the time period during which the total allowable catch is placed on the market shortens. If the original market was for fresh fish, the glut on that market during a short period will lead to lower prices to the fishermen. As fresh prices drop, much of the fishery production may find itself directed to canned or frozen markets.

If the original market was for canned or frozen fish products, prices may still drop. The concentration of the harvest in a short period may impose higher inventory costs on processing and wholesaling firms. The costs of gearing up for short, intensive periods of processing fish may increase the marginal cost of processing the fish. These considerations are also likely to lead to lower prices for the fishermen.

As the season shortens, the demand for processing labor will gradually become concentrated during short periods. Processors, trying to deal with the problems of processing large amounts of fish in short periods, may be forced to import workers from outside of local communities, or to transport fish outside of the communities for further processing. In either case, there may be fewer annual hours of work available for local workers. Short spurts of processing may not provide workers with sufficient time to qualify for unemployment benefits.

Fishermen may deliver lower quality fish since they won't have the time to spend preparing a quality product. Any capital and labor devoted to taking care of the fish once they are on board is capital and labor not devoted to catching more fish. When the fishing season has become very short, the cost of turning capital and labor from harvesting to quality control, as measured by fish not harvested, increases. It becomes more expensive for fishermen to take care of their fish and the quality of the fish they deliver to their customers drops. This will also reduce the prices received by fishermen.

Safety at sea is likely to suffer. The fishery may take place during a very short opening. Under these circumstances, each day a fisherman spends off of the water has a higher cost, in fish not caught, than a day in a more extended fishery. Fishermen are therefore likelier to go out in bad weather than they otherwise would be.

Once the fishermen are out, any limit on fishing activity caused by a concern with safety will have a higher cost in a short opening than it would in a longer fishing period. For example, it may be safer not to overload the boat. If there is a long period in which to fish, the costs, in terms of lost harvest, of making a trip back to port to unload and returning to the fishing grounds, will be less than they would in the short opening. There would thus be increased incentive to overload a boat in the short opening. In addition, the cost of resting during a short opening is relatively high; increased numbers of accidents may result from increased fatigue.

The reduction in safety will reduce the attractiveness of fishing as a job. If it leads to increases in insurance premiums, it will increase the costs of fishing activity, or it will lead to a reduction in insurance coverage.

An extremely important problem, is that fishermen will be using more labor and capital than is necessary to catch the fish. Clark has made a useful distinction between the effectiveness and the efficiency of fishermen.[1] Fishermen, using increasing amounts of increasingly sophisticated capital and labor due to competitive pressures, become increasingly effective at finding and harvesting fish. They learn to do it very well.

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[1]Clark, page 119.

They do not, however, do it efficiently. Efficiency implies a relationship between ends and means. If an end or a goal is not being achieved with the fewest possible means, we speak of an activity as being inefficient. One could as easily say the activity is being pursued in a wasteful manner.

This waste reduces the profits to the fishermen and reduces the social benefits being produced by the fishery. One could argue that precious natural resources, of fuel, wood, steel, human labor, and human ingenuity, are being wasted.

A fishery managed under a total allowable catch that takes place in short period of time may confer an advantage on larger, more capital intensive vessels. If these have a higher rate of harvest they may be better able to take advantage of short openings than smaller vessels. Their ability to operate may also be less constrained by bad weather.

Note that some of these impacts are likely to be setbacks for community development policies in communities that depend on nearby fisheries. One might point to the reduced fish prices, the competitive advantages to fishermen using greater amounts of capital and labor, and the reduction in the hours of processing labor made available to local residents.

The introduction of the total allowable catch in this fishery should allow managers to protect the stocks of fish, since fishing is shut off after the appropriate allowable catch has been taken. Nevertheless, the short fishery may cause some management problems.[2]

Some fishermen may set out more gear, longlines or pots, than they can possibly retrieve before the fishing period ends, in order to get the most fishing done in the short periods. If this gear is left unrecovered after the opening, it may continue to catch and kill fish long after the fishing period has closed.

Fisheries research and inseason management may also be hampered by the short fishing periods. Fisheries managers often use data gathered by port samplers. These men and women, stationed in the ports where landings are made, collect samples of fish and parts of fish landed by the fishermen. These samples are then used for further laboratory research. As the seasons

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[2]In this hypothetical case, the allowable catch was introduced without individual quotas. In other cases, managers considering whether or not to adopt a total allowable catch may be tempted to reject it, despite potential conservation benefits, because it might generate the types of adverse social consequences discussed here. If individual quotas could be adopted as part of the management package, many of the adverse impacts on allowable catches might be offset, and allowable catches would become a much more attractive management tool. It appears that problems with individual quotas may have been one of the reasons for rejecting the use of total allowable catch limits in a recent Australian management plan for shark. Individual quotas appear to have been rejected for enforcement reasons. McGregor notes that the total allowable catch was rejected in part because of "the encouragement it would give to a more intensive use of gear in the early part of each catching year." Page 2-3.

shorten, mistakes in the deployment of port samplers can leave important landings ports underrepresented. A great mass of fish coming over the dock in a short time can make it impossible to take as large a sample of landings as desired.[3]

Individual quota programs are attractive because they can provide a means of dealing with many of these problems.[4]

With the introduction of individual quotas fishermen will find that the activity of other fishermen poses a much smaller threat to their ability to catch a given quantity of fish.

On the assumption that the harvest became concentrated because of competition among the fishermen to catch the fish, there should be a gradual spreading out of the harvest. Many of the problems caused by the shortening of the seasons should be mitigated or resolved.

The potential for spreading out the harvest in a fishery is illustrated by the figure on the next page. This shows the percentage of each year's harvest of chubs taken by Wisconsin's Lake Michigan fishermen in each month for the years from 1979 through 1985. The fishery was shut down during the first quarter of each year (except for small harvests allowed for research purposes), and part of the remaining total allowable catch was released at the start of each subsequent quarter.

The fishery began in 1979, and in 1980, 1981, and 1982 showed a clear pattern of landings concentrated during the first month of each quarter. This pattern was a little less clear cut for the last quarter of each year, when landings appeared to be somewhat more spread out.

In 1983 individual quotas were introduced, at the request of industry, in order to deal with these periodic market gluts. In 1983, the first year the individual quotas were in force, landings remained concentrated in the first month during the first quarter of fishing. However, from the second quarter of fishing in 1983 through the end of the data series presented here, the earlier pattern of landings was not seen. Landings were distributed much more evenly over the course of the year.

The impact of this program on the marketing of chubs is harder to determine for the period after 1985 because of changes in the nature of the fishery during the last few years. In recent years, because of large numbers of small fish and attractive alternative fisheries, many fishermen have not been harvesting their full quotas.[5]

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[3]IPHC Annual Report (1987), page 34.

[4]Individual quotas are not the only means to deal with these problems. The fishery might be spread out by increasing the restrictiveness of effort controls, or by making use of weekly or trip quotas.

[5]For more details on this fishery see Muse and Schelle, "Individual Fisherman's Quotas..."

If an individual quota spreads out the harvest in our hypothetical fishery, many of the problems discussed earlier should gradually solve themselves. Prices to the fishermen should rise as gluts in the market are eliminated and as processors' costs are reduced, demand for processing labor may become more spread out and more of the labor may be supplied locally, the quality of the fish supplied by the fishermen should rise, fishermen should operate more safely, fishermen should operate in a less wasteful manner, the amount of fishing gear left unrecovered should drop, and port sampling should be more effective.

If these events take place in the hypothetical fishery, then the hypothetical value of the fishery to the fishing community, whether value is assumed to mean economic benefits, a particular distribution of income, or the achievement of a less tangible cultural or conservation goal, will arguably be increased. Quality improvements and cost reductions should improve the profitability of the fishery, changes in the residence of the labor used in processing would affect the distribution of income and potentially advance the cultural objective of rural community development, and the reduction in waste in harvesting, reduction in the amount of unrecovered gear, and improvement in port sampling abilities would advance conservation as well as economic objectives.

ADDITIONAL CONSIDERATIONS

A hypothetical example will produce a hypothetical result. This hypothetical example has been set up deliberately to show why individual quotas may be attractive. While the outcomes discussed are plausible in many cases, they are not inevitable. Much will depend on the rules of the specific program or on the nature of the fishery.

In our example, the introduction of the allowable catch was the circumstance that led to a concentration of the fishery in a brief period of time. There are other reasons that a fishery may be concentrated in time, however. The fish may only be available at certain times, as in the Alaska seine and gillnet herring roe fisheries. In other cases, the catch per unit of effort may be very high and may lead to relatively low fishing costs at certain periods. If the fish are going into canned or frozen markets and can be stored for long periods, the reduced fishing costs from fishing when catch rates are expected to be high may offset the increased costs of holding inventories and processing the fish in a brief period. In these cases, the introduction of individual quotas may not spread out the season.

It is possible to conceive of cases in which individual quotas may actually shorten a season. Consider a fishery producing frozen fish products that has a high catch per unit of effort in May, but whose season opens in January. Under a total allowable catch without individual quotas, competitive fishing pressure may force fishermen to operate prior to the favorable fishing conditions in May. Once individual quotas are introduced fishing activity may concentrate in May.

In many of these fisheries individual quotas may still bring benefits. The main change in the discussion is that the individual quotas will not spread out the season as before. Individual quotas may still have a valuable role to play in each of these situations by decreasing management costs, and allowing fishermen to operate more profitably.

Enforcement is going to be an issue in any individual quota program. Fishermen have an incentive to cheat on their quotas by trying to smuggle more fish to market than their quota allows. Fishermen faced with a limit on the amount of fish they can land under their quotas may discard less valuable, or lower quality catches at sea so as to maximize the value of their quota. Fishermen may misreport the area within which they made their harvest in order to fish attractive stocks for which they hold no quota. The dumping of fish and misreporting of areas will often be very hard to monitor.

Enforcement should be considered very carefully before starting a program. Enforcement problems may be a good reason not to start an individual quota program. It appears that a recent Australian shark management plan did not use individual quotas because of potential enforcement problems.[6] An individual quota program begun in the Bay of Fundy herring seine fishery in 1976 was plagued by extremely serious cheating and had to be completely revised in 1983.

Programs do appear to be proceeding relatively successfully in difficult enforcement environments. Programs in Ontario and in Wisconsin's Green Bay yellow perch fishery cover many small scale operators operating in areas where smuggling could be relatively easy. Nevertheless, the viability of these programs is not currently threatened by enforcement problems.

The enforcement environment after the program has begun may be better than before it starts. There is reason to believe that fishermen will be more cooperative with enforcement under individual quotas since they will have a greater stake in the health of the fish stocks. In both New Zealand and Ontario fishermen appear to have been strong proponents of vigorous enforcement. Administrators from both areas note changes in the attitudes of fishermen towards enforcement efforts.[7]

There are incentives to cheat in the absence of individual quota programs. Fishermen might want to underreport in an attempt to beat the tax man. They may misreport the area within which fish were taken through simple carelessness, a desire to keep certain areas open, or because they have been fishing in a closed area. Fishermen may dump fish in an open access fishery. These incentives may be intensified with individual quotas, but they are not absent without them.

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[6]McGregor says individual quotas were rejected "because shark is landed at a number of outlets for the fresh fish market and because of the many private sales outlets which have developed over the years." page 2.

[7]Ontario and Wisconsin discussed in Muse and Schelle, "Individual Fisherman's Quotas...", New Zealand in Muse and Schelle, "New Zealand's ITQ Program," page 29.

Unsuccessful program enforcement may pose problems for biological management. If fishermen cheat and underreport, the total allowable catch, presumably set on the best biological information, will be exceeded. In addition, the misreporting will make it harder to interpret and use landings information for biological research and management.

In our hypothetical example, the individual quota program promoted community development policies in communities that depended on nearby fisheries. The program spread the fishery out in time, raised fish prices, reduced the amount of labor and capital needed to fish, and provided more hours of processing jobs to local residents.

It might also be possible, once the program was begun, to enter quota markets and buy quota to put into the hands of local communities. These communities could then lease the quota. They may want to direct the leases particularly to local residents. Whether the leases went to local residents or not, the income from the leases could be used for community purposes. The problems with this potentially interesting approach are arranging financing for the quota purchases, and establishing a framework in which small remote communities could administrate the quota program in a cost effective manner.

The benefits flowing to communities from the hypothetical individual quota program were hypothetical benefits. Alternative hypothetical programs could have alternative, and less attractive, hypothetical community development outcomes. Some may be concerned that under an individual quota program there might be a net transfer of quota out of remote rural communities. In a more general sense, some might be concerned that residents of other states would have comparative advantages in quota markets that would lead to net out-of-state quota emigration.

Regional transfer issues appear to have been concerns in other places, and may have led to some restrictions on the transferability of quota. Ontario has an individual quota program in its fresh water fisheries and has imposed strong transferability restrictions on quota. No one from out of the province may own quota. Neither may a person transfer quota to another person who has not traditionally fished in an area, unless no one who has traditionally fished in the area is willing to buy it. The program in Atlantic Canada's offshore trawl fishery for groundfish absolutely bans quota sales and severely restricts transfers, perhaps in part due to the same concerns over regional transfers.[8]

Nothing was said, in the hypothetical example, of the potential to accumulate quota in a few hands. Many persons may be concerned that once a program has begun, a small group of persons would buy up large parts of the quota. The benefits from doing this would depend on the potential returns to scale in the fishery, the potential for monopoly profits in the fishery, or the potential to use any market power associated with control over the quota in order to gain control over the fishermen.

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[8]These restrictions are discussed at greater length in Muse and Schelle, "Individual Fisherman's Quotas..."

It may be possible to deter accumulation through limits on the quota any single person or firm could hold. For example, no one may be allowed to hold more than 5% of the total quota. This could raise administrative problems, however, if persons seek loopholes through the limits.

CONCLUSIONS

This discussion has not exhausted the possible benefits of individual quotas, or the possible problems that may be associated with them.

They are not going to be appropriate in every fishery. Obviously, a fishery must have a total allowable catch if individual quotas are to be used. There are many fisheries, including Alaska's salmon fisheries[9], in which this condition will not be met. Enforcement difficulties, or other potential problems may also preclude the use of individual quotas.

Since the seventies, however, individual quotas have become more and more widely used as fisheries management tools. There are now programs in important fisheries in places as diverse as Iceland, Atlantic Canada, Ontario, Wisconsin, New Zealand, and Australia.

Where individual quota rules are appropriate, they can be a powerful means by which the value of fishery resources to society can be increased.

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The opinions in this paper are those of the author. They do not necessarily represent the views of the Alaska Commercial Fisheries Entry Commission, or of any of the persons mentioned in the acknowledgements. Any errors of fact are the responsibility of the author.

[9]Except, possibly, the salmon troll fishery.

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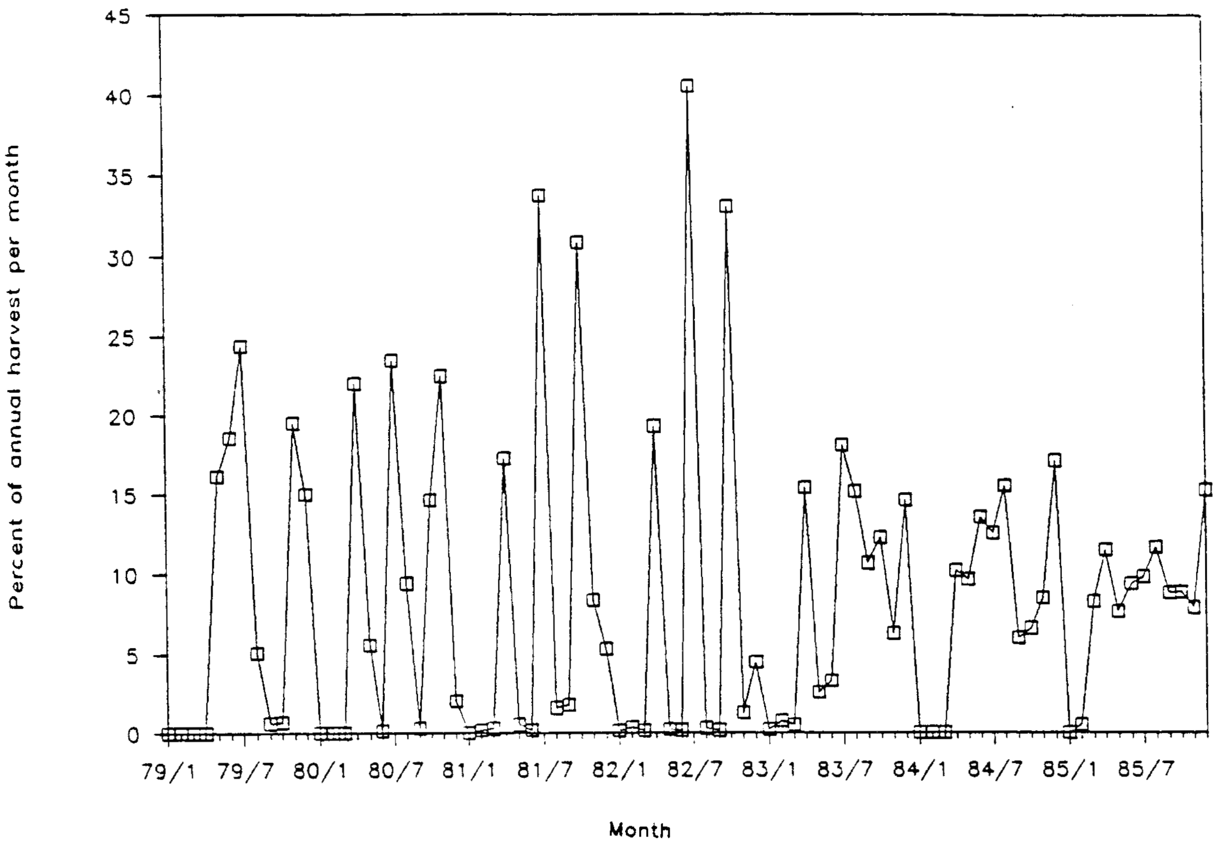

Figure 1. Chub landings from Wisconsin's Lake Michigan gillnet fishery for chubs, 1979-1985, as percent of annual harvest per month. Data provided by the Wisconsin Department of Natural Resources.

COMMERCIAL FISHING INDUSTRY STUDY
HOMER, ALASKA[1 2]

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INTRODUCTION

It is generally recognized that commercial fishing has been the backbone of the Homer Area economy for the past thirty years. Even though diversification in the form of tourism, commercial and government services, and a growing non-fishing population are changing the complexion of the area's economic base, commercial fishing still stands as the single most important industry. At a time when Alaska's oil based economy is severely depressed, healthy fish stocks, relatively high prices and expanding domestic and world markets have made fishing one of the few bright spots in the state's and Homer's economic future.

Things are changing on the southern Kenai. Decisions are being made by the ports and cities, the borough, the state, and the federal government that are going to have economic significance to all industries, all businesses and all people of the area; decisions about port and harbor rates, decisions about taxes and decisions about services. It is vitally important that an industry like commercial fishing "state its case" in the development of the southern Kenai Peninsula. While almost everyone will agree that commercial fishing is an important industry, there are almost no numbers or figures to document the extent of that importance. At the request of the North Pacific Fisherman's Association this study was initiated in an attempt to provide some of the "facts" about the fishing industry in the Homer Area.

This study is basically the piecing together of existing facts that make up this complex industry we call commercial fishing. In addition to sleuthing out existing information, two new sources of information were developed.

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[1] This study is the result of work sponsored by the University of Alaska Sea Grant College Program. Alaska Sea Grant is cooperatively supported by the U.S. Department of Commerce, NOAA Office of the Sea Grant and Extramural Program under grant number NA86AA-D-SG041, project number A/71-01 and A/75-01, and by the University of Alaska with funds appropriated by the state.

[2] The complete results and supporting data for this study are contained in Marine Advisory Bulletin #33, November 1987, available from the Alaska Sea Grant College Program.

One was a survey of commercial fishermen and the other was a survey of area businesses which depend on commercial fishermen for some or all of their business. The year 1985 was selected as the study year because it is the most recent year for which the Alaska Commercial Fisheries Entry Commission (CFEC) has complete statistics. CFEC data is an essential part of the study. The geographical coverage of this study is the southern Kenai Peninsula including the communities of Anchor Point, Nikolaevsk, Homer, Seldovia, Halibut Cove, Port Graham, and English Bay. For the sake of brevity this area will be referred to throughout this report as the Homer Area.

GROSS ECONOMIC IMPACTS

Harvesting Sector

The Commercial Fisheries Entry Commission, a division of the Alaska Department of Fish and Game, annually produces catch and gross earning statistics based on fish ticket landing records. Table 1 shows the 1985 catch data for all fishermen who used Homer, Anchor Point, Seldovia, Port Graham or English Bay as their place of residence on any application to the CFEC.

Table 1. 1985 landings and earnings for fishermen residing in five Homer communities based on ADF&G fish ticket statistics.

Census Area	No. Permit Holders	No. Permits Fished	Pounds Landed	Est. Gross Earnings
Anchor Point	87	149	3,493,442	2,521,901
English Bay	7	7	84,585	50,913
Homer	353	627	32,801,547	18,923,908
Port Graham	19	25	1,418,905	515,064
Seldovia	69	116	5,299,596	4,008,365
Total	535	924	43,098,075	26,020,151

From Table 1 you see that Homer Area fishermen landed more than 43 million pounds of raw fish (including shellfish) in 1985, worth an estimated 26 million dollars.

JOBS/EMPLOYMENT

A good indicator of the economic impact of any industry is the number of jobs created. A difficulty with using this indicator is defining jobs in such a way that they can be meaningfully compared to jobs in other industries. When considering a seasonal industry like commercial fishing it is normal to convert the total number of jobs to a full-time equivalent number of jobs through some kind of hours/day or months/year conversion. While this approach is used here it should be noted that a direct comparison between converted seasonal jobs and full-time jobs may not be appropriate. For instance, the average commercial fishing job lasts about three months, so it would normally take four of these "seasonal" jobs to equal one full-time job. The income earned in three months of fishing, however, is in some cases enough to provide annual living expenses and the fishing crew member or operator does not need or want to seek additional employment. For many fishermen their seasonal job is equivalent to a full-time job.

Another pitfall in analyzing jobs in the fishing industry is equating crew positions with jobs. It is easy to take the average number of crew positions in a fishery, multiply that by the number of permits fished and equate the total to the number of jobs in a fishery. The relationship between crew positions and jobs is not direct. In the Homer Area fleet many captains employ the same crew member in more than one fishery. Therefore, one job may cut across several crew positions. I have attempted to compensate for this by multiplying the total number of crew positions by .7. This factor was derived from information gathered in the commercial fisherman's survey.

The following facts about jobs created by the harvesting sector of the Homer Area commercial fishing industry were also derived from the survey:

1. There were 1,929 crew positions in all fisheries.

2. There were 1,350 seasonal jobs (1,929 x .7).

3. Each seasonal job averages 2.4 months. Therefore, the number of full-time equivalent jobs is 270 $\frac{(1,350 \times 2.4)}{12}$.

4. Homer area residents were employed in 224 of these jobs, so about 83% of these jobs went to locals.

5. Salaries paid to residents ranged from a high of $42,205 (for 5 months) to a low of $600 (2 weeks) with the average being $10,213.

Commercial fishing wages are so variable that it would be difficult to make any kind of economic impact projections based on the average income quoted above. The number of jobs (seasonal and full-time equivalent) are, however, belived to be an indication of commercial fishing's impact in the Homer Area.

COMMERCIAL FISHERMEN'S SURVEY

The purpose in surveying commercial fishermen directly was to get a better understanding of how and where they spend their fishing income. Because of the diverse nature of the Homer Area fleet it was obvious that some portion of their income was spent outside the local area. It was necessary to get an estimate of this exported income and also to get a clear picture of fishermen's local spending patterns.

Fishermen were asked to report on 33 different expense categories. Seven of these expense items are summarized in Table 2. It shows what percent of the total expenditure for each item was spent in the Homer area. Most outboards and boat repairs are purchased locally. Most boat loans go outside of the area. Overall fishermen make 76% of their business related purchases locally.

Table 2. Fisherman's Income Spent in Homer Area

Expenditure	Percent
Outboards	94%
Fuel	72%
Crew shares	88%
Groceries	78%
Boat loans	28%
Accountants/Taxes	82%
Boat repair	89%
Overall	76%

So how does the Homer Area commercial fishing industry impact the local economy? The simple answer is that it contributes over 28 million dollars and over 450 full-time jobs (see Table 3). It would be negligent, however, to leave it at that because the real answer to the above question is not simple.

Table 3. Summary of economic and job impacts discussed in this study.

Industry Sector	$$$	Jobs (Full-time)
Harvesting (Fishermen)	$ 19,760,000	270
Processing (Seward Fish)	6,205,350	105
ADF&G (Commercial Fish)	764,000	11
ADF&G (FRED)	558,000	8
US Coast Guard	121,000	N/A
Tendering/Leasing	1,065,397	N/A
Business sector	(Indirect)	50
Port of Homer	(Indirect)	13
Total	$ 28,473,747	457

Approximately 15% of the households in the Homer Area earn all or part of their annual income from harvesting fish. As many as 1,600 jobs are created by this industry. Over 85% of these jobs go to local people. Even the 15% that don't go to local people benefit the local economy to some extent. They bring new people to the area, some who decide to stay, and all of them spend at least part of their income here. Some of these jobs are seasonal, lasting only three to four months, but they are jobs. Many people prefer seasonal work in the fishing industry to working full-time at something else.

Twenty eight million dollars is the estimated 1985 direct income to the Homer Area provided by the fishing industry. How many times that is multiplied as it works its way through the economy can only be guessed at without further studies, but there is no question that those dollars reach to all corners of the business community.

The infrastructure required to support this industry is substantial. Much of it has been detailed in this study but some has been missed and some of the details could be more complete. Also, the infrastructure is constantly changing. The recent expansion of the Homer boat harbor and the development of the fish dock and ice plant have opened the door for substantial changes in the fishing fleet. Important discussions are also underway as to how and if future development of the harbor and adjacent areas on the Homer Spit should take place. All of these things will impact the commercial fishing industry; just how remains to be seen.

Commercial fishing is a complex industry that touches many parts of the local and state economy with national and international implications as well. This study was never intended to be a comprehensive analysis of the industry, but the results presented here are a realistic beginning.